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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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VOL. CX.—No. 2852.] *LONDON: FRIDAY, AUGUST 27, 1920.* [*Registered at the General Post Office as a Newspaper.*] PRICE... 1s. 2d. BY FOREIGN POST ... 1s. 6d.

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See page 17. 8206

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See Advertisement page 103, Aug. 20.

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See Advertisement page 130. 8187

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High-class GUNMETAL STEAM FITTINGS,
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Yarrow Patent Water-tube Boilers. 8709
Messrs. YARROW & CO., UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

Matthew Paul & Co., Ltd. LEVENFORD WORKS, **Dumbarton.** 8353
See Full Page Advt., page 78, Aug. 20.

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Walter Somers & Co., Ltd., HALESOWEN. 7116

"Delta" Brand HIGH-CLASS ENGINEERING ALLOYS.
Forgings, Castings, Bars, Sheets, Wire, Tubes.
THE DELTA METAL CO., LTD., 9417
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TAYLOR & CHALLEN, LD., Engineers, BIRMINGHAM.
See Full Page Advertisement, Aug. 20.

Diesel Driven Generators, 400-500 Kw., D.C., 500 or 250 Volts, 320 R.P.M., in excellent condition. Low price.
Engines and Dynamos could be sold separately.
Also TWO 500 Kw. Parsons TURBINES, 230-250 Volts, D.C. (in series 460-500 volts), complete with Spare Armature and Condenser.
Exhaust TURBINE SET, Willans-B.C.C., 200 Kw., 440/500 Volts. Complete with Condenser, Pumps, &c.
JENNINGS, West Walls, Newcastle-on-Tyne. 7369

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Steel Castings. 8181
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E. J. Davis, M.I Mech.E., Gas Engines Inspected, Tested and Reported Upon. Over 25 years' experience. Tel.: 736 and 737 Stratford. Wire: "Rapidities, London." —Great Eastern Road, Stratford, E. 15. 1794

Machine and Engineering WORK of all descriptions undertaken for Manufacturers, Patentees, &c. Also repairs and renewals. Best work, moderate charges.—RUSSELL & RUSSELL, LTD., Queen's Wharf, Hammersmith.
NEW PATENT ACT.—ROGERS & RUSSELL, LTD., are prepared to undertake the manufacture of articles at present made abroad, and will be pleased to hear from firms desiring such work executed. 9211

Locomotive Traversers (ELECTRIC). 8143
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Dredging Plant OF ALL DESCRIPTIONS.
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See half-page Advert., last week and next week. 8490

Centrifugals.
Pott, Cassel & Williamson, MOTHERWELL, SCOTLAND. 7941
See half-page Advertisement, page 92, Aug. 6.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, Mount Street, Manchester.
Chief Engineer: C. E. Stromeyer, M.I.C.E.
Founded 1854 by Sir William Fairbairn.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 8443

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Principal:
J. W. WILSON, M.I.C.E., M.Inst.Mech.E.
Founded 1872.

The New Course will commence on Wednesday, September 15th. New Students enter at the School on the Morning of September 14th.
Prospectus, etc., of the PRINCIPAL. J 389

The Polytechnic, Regent STREET, W. 1.

SCHOOL OF ENGINEERING.

President of School—The Hon. Sir Charles Parsons, K.C.B., M.A., LL.D., D.Sc., F.R.S., etc.
Head of Department—Henry J. Spooner, M.I.Mech.E., M.I.Auto.E., A.M.Inst.C.E., F.G.S., etc.
The DAY DEPARTMENT reopens on 14th September, 1920.
Entrance Examination, 13th September, at 10 o'clock.
Three Year DIPLOMA COURSES in MECHANICAL ENGINEERING, ELECTRICAL ENGINEERING, MOTOR CAR ENGINEERING, CIVIL ENGINEERING.

Practice in the Laboratories, Drawing Office, Workshop and Field.
Fees 21 Guineas per annum.
The EVENING DEPARTMENT reopens on 27th September, 1920.
Students enrolled on 15th September, 6 to 8.30 p.m.
Detailed Prospectus of Day and Evening Department 2d. post paid, from the DIRECTOR OF EDUCATION. J 388

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Complete Diploma Courses in MECHANICAL, ELECTRICAL and MINING ENGINEERING. A new Diploma Course has just been instituted in OIL MINING ENGINEERING.

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A Two-Years' Course in Building Construction for Builders' Clerks and Surveyors has been instituted, leading to a Certificate.

Prospectus and information on application to Principal at the College.
PETER MACNAUGHTON, Clerk.
Heriot Trust Offices,
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August, 1920. J 393

Inst. C.E. Exams.—Over 300

successes by Correspondence Coaching. Several prizes. Rec. "D" now prepared. (Designs, Specifications and Quantities). A few vacancies open.—Address, 7494, Offices of Engineering.

Correspondence Courses for

B.Sc., Inst. C.E., I. Mech. E., all ENGINEERING EXAMS. Special Courses and Single Subjects. Personal tuition.—For full particulars apply to Mr. TREVOR W. PHILLIPS, B.Sc. (Hons.), Assoc.M.Inst.C.E., M.R.S.I., etc., 9–10, Trafford Chambers, 58, South John Street, Liverpool. 8432

Inst. C.E., I. Mech. E., B.Sc., and all Engineering Examinations.

—Mr. G. P. KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—39, Victoria St., Westminster, S.W. 8805

Tuition by Post. — Rapid

COACHING for the October Examinations of the I.C.E. and I.M.E. 90% passes last exam. Estab. 1878.—PENNINGTONS, University Tutors, 204, Oxford Road, Manchester. 7963

TENDERS.

INDIA OFFICE, WHITEHALL,
26th AUGUST, 1920.

THE SECRETARY OF STATE FOR INDIA IN COUNCIL is prepared to receive

Tenders from such Persons

as may be willing to supply:
Bearing Plates.
Dog Spikes.
Steel Keys for Sleepers.
Wrought Iron or Mild Steel Hoop.

The Conditions of Contract may be obtained on application to the DIRECTOR-GENERAL of Stores, India Office, Whitehall, S.W. 1., and Tenders are to be delivered at that Office by 2 o'clock p.m., on Tuesday, the 21st September, 1920, after which time no Tender will be received.

G. H. COLLIER,
Director-General of Stores. J 437

CLYDE NAVIGATION.

PLANT FOR SALE AT PRINCE'S DOCK POWER STATION.

The Trustees invite

Tenders for the Purchase of

Two Sets of Hydraulic Vertical Inverted Triple Expansion Surface Condensing PUMPING ENGINES. Cylinders 15·23 and 36 in. dia., Pumps 5 in. dia. by 24 in. stroke, working pressure 150 lbs. per sq. in. Each set capable of supplying 200 gallons per minute at 760 lbs. per sq. in. All branch steam and water pressure pipes and valves connected with these engines above floor level inside Power Station included.

These Pumping Engines are at present in use, and in good working condition, and are to remain on site until notice is given by the Mechanical Engineer that they are to be moved.

Additional information and Permit to inspect can be obtained here at the Mechanical Engineer's Office.

Tenders to be lodged with the undersigned not later than Monday, 20th September, 1920.

The Trustees may not accept the highest or any tender.

T. R. MACKENZIE,
General Manager & Secretary.

16, Robertson Street,
Glasgow.
25th August, 1920. J 463

EDINBURGH CORPORATION.
ELECTRICITY SUPPLY.

The Lord Provost, Magistrates and Council invite

Tenders for the following

PLANT at the Portobello Generating Station:—

Specification No. 21—Coal, Ash and Flue Dust Handling Plant.
Specification No. 28.—Circulating Pumps and Pipe Work.

Copies of the Specifications can be obtained from the Engineer, Dewar Place, Edinburgh, on and after 30th August, upon payment of a deposit of £3 3s., for each section. Additional copies of the Specifications can be obtained upon payment of a deposit of £1 1s. each; these deposits to be returned after receipt of a bona fide Tender and on return of the Specification.

The Specifications can be seen at, but not obtained from, the office of Sir Alexander Kennedy, 17, Victoria Street, Westminster, London, S.W.

Tenders on the prescribed form, enclosed in a sealed envelope and endorsed on the outside "Electricity Supply Tender for Specification No. 27 or 28, as the case may be, must be delivered at the office of the undersigned not later than 27th September, at 10 a.m.

The Council do not bind themselves to accept the lowest or any offer.

A. GRIBBON,
S.S.C.,
Town Clerk.

City Chambers,
EDINBURGH, 25th August, 1920. J 442

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD.
(Plant and Machinery Section.)

For Sale by Public Tender.

HYDROGEN PLANT.

Comprising:—

One Hydraulic Lift with 6 ft. 6 in. square platform (by E. G. Smith & Sons, Halifax).
Three Steel Chimneys, 18 in. dia. by 50 ft. high.
Three Water Gas Exhausters each 30,000 cu. ft. hourly capacity (Bryan & Donkin).
Three Hydrogen Exhausters, each 10,000 cu. ft. hourly capacity (Bryan & Donkin).
Two Lancashire Boilers, 7 ft. dia. by 30 in. (complete) and
Two Sets Forced Draught Furnaces for same (part finished).
One Lancashire Boiler, 6 ft. 6 in. by 30 ft. (only partly finished) and
One Set Forced Draught Furnaces for same.
One Hydrogen Station Meter, 27,000 cu. ft. per hour and
12 15 in. gauges.

Detailed particulars, Permit to view and Tender Forms can be obtained upon application to the CONTROLLER, D.B.1.e., Plant and Machinery Section, Charing Cross Huts, Embankment, W.C. 2. Applications should be sent in not later than Ten a.m., September 7th, 1920. J 260

TYNEMOUTH CORPORATION ELECTRICITY WORKS.

TRIPLE EXPANSION STEAM DYNAMO AND BOILERS FOR SALE.

The following Plant is for

SALE by TENDER—

One 500 k.w. Shunt and Compound Dynamo, 440 to 550 volts, by Siemens, coupled to triple expansion engine by Bellise & Morcom.
Two Exhaust Steam Oil Separators.
One Surface Condensing Plant by the Wallsend Slipway & Engineering Co., Ltd., with Edwards three throw Air Pumps, direct driven by Electric Motor.
One Centrifugal Circulating Pump for same, direct driven by Electric Motor.
One Cooling Tower for same.
Four Lancashire Boilers 30 ft. by 8 ft. 6 in., 180 pounds working pressure with mechanical stokers and three fitted with superheaters.
One Climax Watertube Boiler suitable for 15,000 pounds per hour, 200 pounds working pressure.
9 in. Steel Steam Pipes and Valves connected with the above.
Three Weir Feed Pumps, Feed Pipes and Valves connected with the above.
Two 3 in. Invincible Centrifugal Pumps by Gwynne & Co., 3 in. bore, electrically driven.
One Vertical Duplex Pump by Lamont & Co., Paisley, cylinders 5 in., stroke 6 in., suction 3½ in.
Coal Bunkers and Conveyor with Motors.

The above are for sale at Tynemouth Corporation Electricity Works and may be seen by appointment.

For further particulars apply to C. TURNBULL, M.I.E.E., Borough Electrical Engineer, Tynemouth. J 330

THE HIGH COMMISSIONER for New Zealand is prepared to receive

Tenders for the Supply of

2,250 ton B.S. 100 lb. FLAT BOTTOMED RAILS and FISHPLATES.

The Specification, Conditions of Contract and Form of Tender may be obtained on application to the High Commissioner for New Zealand, 415, Strand, London, W.C. 2. Tenders are to be delivered at the Offices of the High Commissioner for New Zealand by noon on 2nd September, 1920, after which time no tender will be received.

The High Commissioner for New Zealand does not bind himself to accept the lowest or any Tender, or to defray any expenses in connection with tendering. J 451

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED,
are prepared to receive

Tenders for the Supply of

FIVE "M" CLASS 4-6-0 SUPERHEATED LOCOMOTIVE ENGINES AND TENDERS.

Specifications and Forms of Tender may be obtained at the Company's Offices, 91, York Street, Westminster, S.W. 1.

Tenders addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked "Tenders for Locomotives" must be left with the undersigned not later than 2 p.m. on Tuesday, 28th September, 1920.

A charge, which will not be returned, will be made of £3 for each copy of the Specification. Copies of the Drawings may be obtained at the Office of Robert White, Esq., M. Inst. R.E., Consulting Engineer to the Company, 3, Victoria Street, Westminster, S.W. 1.

By Order,
W. B. REYNOLDS,
for Managing Director.

91, York Street,
Westminster, S.W. 1.
18th August, 1920. J420

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD
(Plant and Machinery Section).

FOR SALE BY PUBLIC TENDER

Two Gas Holders and

MISCELLANEOUS PLANT,
Comprising;

Two Steel Gas Holders, 40,000 cu. ft. capacity each.
One Vertical Boiler, 10 ft. high, 4 ft. dia. Complete with Tangye Duplex Steam Water Feed Pump.
One Gas Engine and Exhauster with 6 in. connections.
Two W.I. Circular Scrubbers for washing ammonia.
One Cast-iron Pipe Condenser.
Two 15 ft. by 8 ft. Cast Iron Luted Purifiers—also two 6 ft. 6 in. by 6 ft. 6 in. " "
One Overhead Gantry, with cast-iron pulleys, &c.
One Small Derrick.
Five Settings of 6 Retorts, with necessary 6 in. Cast Iron Pipe.
Five Steel Hydraulic Mains.
One Cast Iron Station Gas Meter.
One 4 ton Weighbridge with Still Yard (by Pooley).
50 ft. 6 in. S. & S. Pipe, and
About 5 tons of Cast Iron connections underground.
Lying at Sandhurst.

Detailed particulars, Permits to View, Tender Forms, which must be completed and returned not later than 10 a.m. on the 4th of September next, can be obtained upon application to the CONTROLLER, D.B.1 e., Plant & Machinery Section, Charing Cross Huts, Embankment, W.C. 2. J 256

APPOINTMENTS OPEN.

BENARES HINDU UNIVERSITY.

ENGINEERING COLLEGE.

Applications are Invited for

the POST of PROFESSOR of MECHANICAL ENGINEERING. Candidates must possess good practical experience and a University degree or academic qualifications of approved standard in Mechanical Engineering. Salary Rs. 500—750 per month.

Apply, PRINCIPAL, Engineering College, Benares Hindu University.
Tel, "Bonco" Benares. J 189

NORTHAMPTON POLYTECHNIC INSTITUTE.

CIVIL AND MECHANICAL ENGINEERING DEPARTMENT.

ELECTRICAL ENGINEERING AND APPLIED PHYSICS DEPARTMENT.

Wanted, an Assistant

LECTURER and DEMONSTRATOR in each of the above Departments. Commencing salary £300 per annum.

Conditions and forms of application, which must be returned not later than Tuesday, 31st August, 1920, can be obtained from—

R. MULLINEUX WALMSLEY, D.Sc.,
Principal.
J 343

12 Foremen of Works

REQUIRED by the Government of the Tanganyika Territory in the Public Works Department for a tour of from 20 to 30 months' continuous residential service with possible extension. Salary £260, rising by annual increments of £15 to £350 per annum. Outfit allowance on first appointment of £30. Quarters free of rent, and free passages and liberal leave in England on full salary.

Candidates, preferably single, age 25 to 30, who must have served in some branch of His Majesty's Forces during the late war unless their reasons for not doing so are entirely satisfactory, and who have served an apprenticeship as a carpenter and have a sound knowledge of building construction, should apply at once, by letter, stating age, whether married or single, and full particulars of experience, to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting M, 10088. J 474

COUNTY BOROUGH OF WEST HAM.

MUNICIPAL TECHNICAL INSTITUTE.
Romford Road, Stratford, E. 15.

Two Full-Time Assistant

LECTURERS and DEMONSTRATORS in Mechanical Engineering WANTED for next Session. Salary £300—£15—£325 per annum.

Must be graduates of British University.

Applications, with particulars of qualifications and copies of recent testimonials, should be sent to the PRINCIPAL, Municipal Technical Institute, Romford Road, E. 15, not later than 5th September, 1920. J 199

MANCHESTER CORPORATION WATERWORKS.

LAYING OF AN ADDITIONAL PIPE LINE BETWEEN THIRLMERE AND MANCHESTER.

The Waterworks Committee require the

Services of Several Assistant

CIVIL ENGINEERS in connection with the laying of an additional pipe line between Thirlmere and Manchester.

Candidates must be good Surveyors, with experience in the preparation of detail drawings, specifications, and the setting out and laying of large pipe lines through difficult country.

Application forms, which can be obtained from the SECRETARY, Waterworks Department, Town Hall, Manchester, must be sent in not later than the 11th of September, 1920. J 357

COUNTY BOROUGH OF STOKE-ON-TRENT.

CENTRAL SCHOOL OF SCIENCE AND TECHNOLOGY, STOKE-UPON-TRENT, ENGINEERING DEPARTMENT.

The Governors invite

Applications for the Post of

LECTURER in MECHANICAL ENGINEERING.

Candidates should hold a University Degree or an equivalent qualification, and must also have had teaching and works experience.

The commencing salary will be £350 to £400 per annum.

Forms of Application, which should be returned, duly completed, as early as possible, and further particulars may be obtained on receipt of stamped, addressed foolscap envelope from

DR. W. LUDFORD FREEMAN,
Director of Education.
Education Offices, Town Hall,
Hanley,
Stoke-on-Trent.
30th July, 1920. J 326

TEMPORARY ENGINEERS REQUIRED IN CONNECTION WITH HYDRO-ELECTRIC SURVEYS IN BOMBAY AND BURMA.

THE SECRETARY OF STATE FOR INDIA IN COUNCIL will make

Six Appointments of

TEMPORARY ENGINEERS for employment in connection with the Hydro-Electric Surveys in Bombay and Burma. Candidates should be between 27 and 35 years of age. Associate Members of the Institution of Civil Engineers and Associate Members of the Institution of Electrical Engineers (London) will be eligible for appointment. Candidates should have a general knowledge of Civil Engineering, including Surveying and the use of the tacheometric plane tables, a sufficient knowledge of electrical power stations and distribution to enable them to draw up projects in the preliminary stages, and some experience of water power.

The appointments will be on agreements for three years with provision for extension by mutual consent. Pay from Rs. 675 to Rs. 1175 per mensem, according to age, commencing from date of reporting for duty in Bombay or Burma. Travelling allowances, leave and Provident Fund on usual conditions applicable to similar appointments in India. Free passages out and home.

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India Office,
9th August, 1920. J 298

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HEAT TRANSFER IN FLUES.

By Lawford H. Fry.

I. Laws Governing Heat Transfer.

In Engineering for February 19, 1909, the writer analysed a series of tests of locomotive boilers, and in this connection gave some attention to the rate of heat transfer in the boiler flues. The data available at that time were not sufficient to lead to a conclusive solution of the problem, and although it was recognised that the rate of heat transfer depended on the rate of flow of the gas, on the diameter of the flue, and on the temperature of the gas, yet the exact effect of each of these factors could not be established. More recent work with a wider collection of experimental data has led to the development of an expression which covers the transfer of heat between a flowing gas and the flue in which it is contained for a wide range of conditions.

In the present article the rate of heat transfer is studied in its relation to the various factors on which it depends. These factors are :—

1. *Temperature.*—The rate of heat transfer depends on the ratio of the temperature of the gas to the temperature of the flue wall. If the flue wall has a mean temperature t, and if the mean gas temperature at one section of the flue is T_1 and at another section x ft. distant along the flue is T_2, all temperatures being measured from absolute zero in any scale, the relation between the two gas temperatures is given by the equation :

$$\text{lolog } T_1/t - \text{lolog } T_2/t = M x \quad . \quad . \quad (1)$$

where "lolog" means "the logarithm of the logarithm," and where M is a constant for a given set of conditions being determined by the dimensions of the flue and by the rate at which the gas flows through it.

2. *Flue Dimensions.*—The two dimensions on which the above constant M and hence the rate of heat transfer depends, are the perimeter and the mean hydraulic depth. The mean hydraulic depth is the area divided by the perimeter, and in a circular flue is one-fourth of the diameter. When circular flues only are under consideration it is simpler and equally accurate to speak of the effect of the flue diameter instead of the effect of the hydraulic depth. This will be done in the present article, the symbol d being used to represent the flue diameter in inches. If the equations thus established are to be applied to annular or other non-circular flues, it is only necessary to replace d by $4h$ where h is the mean hydraulic depth.

3. *Rate of Flow of Gas.*—The effect of the rate of gas flow on the rate of heat transfer is dependent on the weight of gas flowing per hour per inch of flue perimeter. Expressed in symbols this statement is to the effect that the coefficient M in equation (1) varies with the ratio W/p, where W is the weight of gas flowing in pounds per hour, and p is the flue perimeter in inches.

The relation between the flue dimensions, the rate of gas flow and the coefficient M is that given by the following equations :

$$\log M = B + m \log W/p \quad . \quad (2)$$

where :

$$\log (B + 1{\cdot}3) = \bar{1}{\cdot}71 - 0{\cdot}54 \log d \quad (3a)$$

and

$$\log m = \bar{1}{\cdot}38 + 0{\cdot}37 \log d \quad (3b)$$

The derivation of these equations from the experimental data is discussed below, but attention is first directed to the conditions of heat transfer disclosed by the formulæ.

Equations (2), (3a) and (3b) show that for a given flue with gas flowing at a constant rate, the coefficient M in equation (1) is a constant. This means that if distances along the flue x are measured from a point at which the gas temperature is T, the gas temperature T at any other point is given by the equation :

$$\text{lolog } T/t = \text{lolog } T_1/t - Mx \quad (1a)$$

This is to say the logarithm of the logarithm of the ratio of gas temperature to flue temperature (lolog T/t), falls by a straight line law along the flue. The slope of the line giving this fall of the lolog of the temperature ratio is measured by the coefficient M.

It will be seen that this equation enables a determination to be made of the heat transferred from gas to flue in any section of the flue, not, as has been usually attempted hitherto, by ascertaining the rate of heat transfer per square foot of flue area ; but by finding the temperature loss of gas. This, when the weight of gas and the specific heat are known, is a direct measure of the heat loss of the gas, that is of the heat transferred to the flue.

From the form of equation (1a) it is obvious that a large value of M corresponds to a rapid drop of temperature along the flue, that is to a rapid rate of heat transfer. It is of interest to see how the value of M is affected by the three factors—flue diameter, flue perimeter and rate of gas flow—on which it depends. This is shown in Table I, which gives values of M for flues from ¼ in. to 8 in. in diameter, with rates of flow from 100 lb. to 1,000 lb. per hour. It will be seen that with a given flue diameter the value of M, which measures the rate of temperature drop along the flue, falls off as the rate of flow is increased. This is the logical consequence of increasing the amount of gas (heat) offered per unit of flue surface.

It also appears that with a given rate of gas flow an increase in flue diameter causes a decrease in the rate of temperature drop. This is explainable by the fact that though the flue surface per pound of gas is increased, yet this is more than offset by the increase in the hydraulic depth of the flue which causes the contact between gas and flue wall to become less intimate. To make the comparison more explicit, Table II has been compiled to show the length of flue necessary to reduce the gas temperature from an initial value of 2,000 deg. to 720 deg. F., with a flue-wall temperature of 380 deg. F. This latter temperature corresponds closely to that of a flue in a boiler carrying 180 lb. per square inch steam pressure. It appears from this table that with a ½-in. flue, the above temperature drop will take place in 3·76 ft. with a flow of 100 lb. per hour, while a length of 6·15 ft. will be required for the same temperature drop with a flow of 1,000 lb. per hour. It should be noted that the temperature drop being the same in all cases in this table, the heat given up per pound of gas will be the same. If the gas be products of combustion having an instantaneous specific heat $C_p = 0{\cdot}245 +$

Table I.—*Values of Coefficient* M *for Various Flue Diameters and Rates of Gas Flow.*

(Values of M.)

W =	100 lb./hr.	200 lb./hr.	400 lb./hr.	800 lb./hr.	1,600 lb./hr.
d in.					
0·5	0·133	0·117	0·104	0·092	0·081
1·0	0·074	0·063	0·054	0·046	0·039
2·0	0·050	0·040	0·033	0·027	0·022
4·0	0·040	0·030	0·023	0·018	0·014
8·0	0·037	0·026	0·019	0·013	0·009

Table II.—*Flue Lengths Corresponding to a Drop of Temperature from* 2,000 *deg. in* 720 *deg. F. with Various Flue Diameters and Rates of Flow.*

(Flue lengths in feet.)

W =	100 lb./hr.	200 lb./hr.	400 lb./hr.	800 lb./hr.	1,600 lb./hr.
d in.					
0·5	3·76	4·27	4·80	5·46	6·15
1·0	6·80	7·91	9·30	10·9	12·8
2·0	10·6	12·4	15·2	18·6	22·8
4·0	12·6	16·5	21·6	28·2	36·6
8·0	13·8	19·0	26·7	37·7	53·0

Table III.—*Final Temperatures for an Initial Temperature of* 2,000 *deg. F. and a Flue Length of* 5 *ft. with Various Flue Diameters and Rates of Flow.*

(5-ft. flue initial temperature 2,000 deg. F. Final temperatures.)

W =	100 lb./hr.	200 lb./hr.	400 lb./hr.	800 lb./hr.	1,600 lb./hr.
d in.	deg.	deg.	deg.	deg.	deg.
0·5	600	650	705	760	825
1·0	870	930	1,040	1,125	1,210
2·0	1,080	1,190	1,300	1,390	1,475
4·0	1,205	1,340	1,455	1,560	1,655
8·0	1,240	1,390	1,545	1,660	1,745

Table IV.—*Heat given up by Gas in Flowing through a Flue Length of* 5 *ft. from an Initial Temperature of* 2,000 *deg. F., as in Table III.*

(Total heat transferred in 1,000's of British thermal units per hour.)

W =	100 lb./hr.	200 lb./hr.	400 lb./hr.	800 lb./hr.	1,600 lb./hr.
d in.					
0·5	45·2	87·6	169	325	620
1·0	37·4	79·6	130	236	432
2·0	31·0	55·2	96	168	294
4·0	27·2	45·6	68	123	192
8·0	26·0	42·0	54	96	136

Table V.—*Heat given up by each Pound of Gas in Flowing through a Flue Length of* 5 *ft. from an Initial Temperature of* 2,000 *deg. F., as Tables III and IV.*

(5-ft. flue initial temperature 2,000 deg. F. Heat units lost per pound of gas.)

W =	100 lb./hr.	200 lb./hr.	400 lb./hr.	800 lb./hr.	1,600 lb./hr.
d in.					
0·5	452	438	422	406	387
1·0	374	348	324	296	270
2·0	310	276	240	210	184
4·0	272	228	170	154	120
8·0	260	210	160	120	85

Table VI.—*Heat given up by each Pound of Gas in Flowing through a Flue Length of* 5 *ft. from an Initial Temperature of* 3,000 *deg. F.*

(5-ft. flue initial temperature 3,000 deg. F. Heat units lost per pound of gas.)

W =	100 lb./hr.	200 lb./hr.	400 lb./hr.	800 lb./hr.	1,600 lb./hr.
d in.					
0·5	825	801	751	736	727
1·0	707	665	628	570	530
2·0	600	541	480	427	370
4·0	536	459	382	330	255
8·0	515	417	360	284	194

Table VII.—*Final Temperatures for a Flue Length of* 5 *ft., an Initial Temperature of* 3,000 *deg. F., and Various Flue Diameters and Rates of Flow.*

(5-ft. flue initial temperature 3,000 deg. F. Final temperatures.)

W =	100 lb./hr.	200 lb./hr.	400 lb./hr.	800 lb./hr.	1,600 lb./hr.
d in.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.
0·5	682	760	830	880	1,030
1·0	1,080	1,210	1,340	1,475	1,620
2·0	1,410	1,590	1,760	1,915	2,065
4·0	1,600	1,820	2,030	2,205	2,370
8·0	1,660	1,940	2,100	2,380	2,580

Table VIII.—*Final Temperatures for a Flue Length of* 5 *ft., and an Initial Temperature of* 2,000 *deg. F., with Various Flue Diameters and Rate of Flow, showing Effect of Varying Flue-Wall Temperatures.*

(5-ft. flue initial temperature 2,000 deg. F. Final temperatures.)

d =	0·5 in.		8·0 in.	
W =	100 lb./hr.	1,600 lb./hr.	100 lb./hr.	1,600 lb./hr.
t deg. F.	deg. F.	deg. F.	deg. F.	deg. F.
380	600	825	1,240	1,743
400	620	840	1,250	1,748
420	640	860	1,260	1,754
440	660	880	1,275	1,759
Differences 60	60	55	35	16

Table IX.—*Values of Coefficients* m *and* B *for Flues of Various Diameters.*

d	B	m	d	B	m
in.			in.		
0·25	$\bar{1}{\cdot}561$	0·160	1·50	$\bar{1}{\cdot}112$	0·296
0·44	$\bar{1}{\cdot}500$	0·169	2·0	$\bar{1}{\cdot}053$	0·296
0·50	$\bar{1}{\cdot}444$	0·178	2·25	$\bar{1}{\cdot}031$	0·309
0·58	$\bar{1}{\cdot}388$	0·188	2·5	$\bar{1}{\cdot}013$	0·321
0·66	$\bar{1}{\cdot}341$	0·197	3·0	$\bar{2}{\cdot}983$	0·342
0·75	$\bar{1}{\cdot}300$	0·205	3·5	$\bar{2}{\cdot}961$	0·364
0·87	$\bar{1}{\cdot}253$	0·218	4·0	$\bar{2}{\cdot}943$	0·382
1·00	$\bar{1}{\cdot}213$	0·229	5·0	$\bar{2}{\cdot}915$	0·415
1·15	$\bar{1}{\cdot}175$	0·242	6·0	$\bar{2}{\cdot}895$	0·445
1·30	$\bar{1}{\cdot}145$	0·252	8·0	$\bar{2}{\cdot}867$	0·494

0·000030 T g, where T g is the gas temperature in degrees Fahrenheit, the heat lost in falling from 2,000 deg. to 720 deg. F. will be 418 British thermal units per pound of gas. Therefore, with a flow of 100 lb. of gas per hour there will be transferred from gas to flue, 41,800 British thermal units per hour; and with 1,600 lb. of gas per hour the rate of heat transfer will be 16 times as great, or 668,800 British thermal units per hour. To obtain this greater rate of transfer the flue length has been increased from 3·76 ft. to 6·15 ft., that is, in the proportion of 1 to 1·63. The surface of the flue has been increased in the same proportion, from 0·49 sq. ft. to 0·80 sq. ft. Therefore the rate of heat transfer has been increased from 85,000 British thermal units to 830,000 British thermal units per square foot per hour, by increasing the rate of gas flow from 100 lb. to 1,600 lb. per hour.

By comparing the lengths required in flues of various diameters to give the same temperature drop with the same rate of gas flow, it becomes apparent that the rate of heat transfer falls off rapidly as the flue diameter is increased. Thus with 400 lb. of gas passing per hour the flue length required to reduce the temperature from 2,000 deg. to 720 deg. F. is 4·80 ft. for a ½-in. flue and 26·7 ft. for an 8-in. flue. With an increase in diameter in the proportion of 16 to 1 it is necessary to increase the heating surface in the proportion of 89 to 1 to transfer the same quantity of heat. The same effect is brought out in Tables III, IV and V, which show the temperature drop and the amount of heat transferred in flues 5 ft. long when the flue diameter and rate of gas flow are varied. In Table II the flue length was varied to obtain the same temperature drop—from 2,000 deg. to 720 deg. F.—while in Tables III, IV and V the flue length is held constant at 5 ft. and the initial temperature at 2,000 deg. F. Table III shows the final temperatures under these conditions. In a ½-in. flue with 100 lb. of gas per hour, the final temperature is 600 deg. F., while with 1,600 lb. of gas the final temperature rises to 825 deg. F. Tables IV and V show that these temperatures correspond at 100 lb. of gas per hour to a transfer of 452 British thermal units from each pound of gas, and a total transfer of 45,200 British thermal units per hour, and at 1,600 lb. of gas per hour to a transfer of 387 British thermal units per pound of gas, making a total of 620,000 British thermal units per hour. The explanation of this is, apparently, that with the increase in the rate of flow from 100 lb. to 1,600 lb. per hour, each pound of gas remains in the flue a shorter time, and consequently can only give up a smaller amount of heat, 387 British thermal units instead of 452 British thermal units, but the larger number of pounds of gas more than offsets this and gives a very much larger total heat transfer per hour. The effect of increasing flue diameter in increasing the final temperature, that is in reducing the amount of heat transfer, is clearly shown by these tables. Tables I to VII illustrate the effect on the heat transfer of varying the flue length, the flue diameter, the rate of gas flow, and the gas temperature, that is all of the possible factors except the temperature of the flue wall. The effect of varying this temperature is shown in Table VIII. The 5-ft. flue length and 2,000 deg. F initial gas temperature are assumed as in Tables III, IV and V, and the final gas temperatures calculated for wall temperatures of 380 deg., 400 deg., 420 deg. and 440 deg. F. This is done for flue diameters of ½ in. and 8 in., and rates of flow of 100 lb. and 1,600 lb. of gas per hour. It will be seen that the influence of the flue wall temperature depends on the final temperature obtained. With the ½-in. flue and the low rate of gas flow, of 100 lb. per hour, where the heat transfer has been active enough to give the low final temperature of 600 deg. F., an increase of 60 deg. in the wall temperature produces the same increase of 60 deg. in the final gas temperature. With the large flue and high rate of flow (8 in. and 1,600 lb. per hour) the final temperature stands at the high figure of 1,743 deg. F., and the 60 deg. increase in wall temperature produces an increase of only 16 deg. in the final gas temperature. At intermediate values of the final temperature intermediate results are shown.

II. Practical Application of Formulæ.

In order to facilitate the practical use of the formulæ, Tables IX and X have been prepared. Table X gives values of the coefficient M for a

TABLE X.

Pounds of Gas per inch of perimeter per hr. W/P	VALUES OF COEFFICIENT "M." d = Inside Diameter of Flue in Inches.																					W/P
	d. 0·38	0·44	0·50	0·53	0·66	0·75	0·87	1·00	1·15	1·20	1·50	1·75	2·00	2·25	2·50	3·00	3·50	4·00	5·00	6·0	8·0	
2·00	0·238	0·231	0·246	0·215	0·1915	0·1725	0·1540	0·1390	0·1265	0·1170	0·1080	0·0986	0·0920	0·0866	0·0824	0·0758	0·0710	0·0673	0·0616	0·0577	0·0522	2·00
2·83	0·210	0·285	0·231	0·201	0·1790	0·1603	0·1420	0·1290	0·1165	0·1075	0·0985	0·0895	0·0831	0·0780	0·0738	0·0674	0·0625	0·0589	0·0534	0·0494	0·0440	2·83
4·00	0·292	0·250	0·217	0·188	0·1670	0·1493	0·1320	0·1190	0·1070	0·0983	0·0897	0·0811	0·0750	0·0700	0·0659	0·0598	0·0551	0·0517	0·0462	0·0424	0·0371	4·00
5·66	0·276	0·236	0·204	0·176	0·1563	0·1390	0·1225	0·110	0·1009	0·0901	0·0818	0·0736	0·0677	0·0630	0·0590	0·0532	0·0485	0·0452	0·0401	0·0363	0·0312	5·66
8·00	0·261	0·222	0·192	0·166	0·1460	0·1290	0·1135	0·1015	0·0903	0·0826	0·0746	0·0667	0·0611	0·0565	0·0527	0·0472	0·0427	0·0396	0·0347	0·0311	0·0263	8·00
11·3	0·246	0·210	0·180	0·155	0·1360	0·1205	0·1053	0·0935	0·0851	0·0756	0·0680	0·0602	0·0552	0·0507	0·0472	0·0420	0·0377	0·0347	0·0300	0·0266	0·0222	11·3
16·0	0·233	0·198	0·169	0·145	0·1270	0·1120	0·0974	0·0864	0·0763	0·0693	0·0621	0·0543	0·0498	0·0455	0·0422	0·0372	0·0332	0·0304	0·0260	0·0228	0·0187	16·0
22·6	0·221	0·186	0·159	0·136	0·1187	0·1043	0·0903	0·0800	0·0703	0·0635	0·0566	0·0493	0·0450	0·0409	0·0378	0·0331	0·0292	0·0266	0·0225	0·0196	0·0157	22·6
32·0	0·209	0·176	0·150	0·127	0·1110	0·0970	0·0837	0·0738	0·0645	0·0582	0·0516	0·0451	0·0405	0·0367	0·0338	0·0294	0·0258	0·0233	0·0195	0·0168	0·0133	32·0
45·2	0·198	0·166	0·141	0·119	0·1035	0·0903	0·0776	0·0682	0·0594	0·0533	0·0471	0·0409	0·0366	0·0329	0·0303	0·0261	0·0227	0·0204	0·0169	0·0144	0·0112	45·2
64·0	0·187	0·157	0·133	0·112	0·0965	0·0840	0·0720	0·0631	0·0546	0·0489	0·0430	0·0371	0·0329	0·0296	0·0270	0·0232	0·0200	0·0179	0·0146	0·0123	0·0094	64·0
90·5	0·177	0·148	0·125	0·1047	0·0903	0·0781	0·0667	0·0583	0·0502	0·0448	0·0392	0·0336	0·0303	0·0265	0·0242	0·0206	0·0176	0·0157	0·0127	0·0106	0·00794	90·5
128·0	0·167	0·139	0·117	0·0981	0·0843	0·0727	0·0618	0·0538	0·0461	0·0410	0·0357	0·0305	0·0268	0·0239	0·0217	0·0183	0·0155	0·0137	0·0110	0·00905	0·00670	128·00
181·0	0·158	0·131	0·110	0·0918	0·0788	0·0677	0·0573	0·0498	0·0425	0·0376	0·0328	0·0276	0·0242	0·0215	0·0194	0·0162	0·0137	0·0120	0·0095	0·00776	0·00568	181·00
256·0	0·150	0·124	0·104	0·0861	0·0736	0·0630	0·0531	0·0459	0·0390	0·0344	0·0297	0·0250	0·0219	0·0193	0·0173	0·0144	0·0120	0·0106	0·0082	0·00668	0·00475	256·00
362·0	0·142	0·117	0·0974	0·0807	0·0688	0·0586	0·0492	0·0425	0·0359	0·0315	0·0271	0·0227	0·0198	0·0173	0·0155	0·0128	0·0106	0·0092	0·0071	0·00570	0·00401	362·00
512·0	0·134	0·110	0·0916	0·0756	0·0645	0·0546	0·0456	0·0392	0·0329	0·0289	0·0247	0·0206	0·0178	0·0155	0·0139	0·0114	0·0094	0·0081	0·0062	0·00489	0·00336	512·00
724·0	0·127	0·104	0·0862	0·0710	0·0601	0·0508	0·0422	0·0361	0·0303	0·0265	0·0225	0·0187	0·0161	0·0140	0·0124	0·0101	0·0082	0·0071	0·0053	0·00419	0·00284	724·00
1,024·0	0·120	0·098	0·0811	0·0665	0·0561	0·0473	0·0392	0·0334	0·0278	0·0242	0·0205	0·0169	0·0145	0·0125	0·0111	0·0090	0·0072	0·0062	0·0046	0·00359	0·00242	1,024·0

number of flue diameters and rates of gas flow, while Table IX gives, for various flue diameters, the intermediate coefficients m and B which are used in establishing the coefficient M. The relation of m and B to the flue diameter is given by the equations:

$$\log (1·3 + B) = \bar{1}·71 - 0·54 \log d \quad . \quad (3a)$$

and

$$\log m = \bar{1}·36 + 0·37 \log d \quad . \quad (3b)$$

Values of B and m from these equations are given in Table IX for flue diameters from 0·38 in. to 8 in. The flue diameters chosen for the table have been graduated so that the values of the coefficients for any intermediate diameter not given in the table can be found by proportional interpolation between the two nearest diameters given.

The values of the coefficient M given in Table X are calculated from the equation:

$$\log M = B - m \log W/p \quad . \quad . \quad (1)$$

where W is the weight of gas in pounds flowing per hour through the flue and p is the flue perimeter in inches. This table covers the same flue diameters as Table IX and rates of flow from 2 lb. to 1024 lb. of gas per inch of perimeter per hour. The gradations in the rates of flow in the table have been chosen so that, as in the case of the flue diameters, interpolation can be made on a proportional basis between any two values.

Such interpolation is a simple matter of direct proportion if the given flue diameter is one of those shown in the tables and interpolation for the rate of flow is necessary, or if the given rate of flow is covered by the tables and interpolation for diameter required. Where neither diameter nor flow appears in the tables the interpolation process is slightly longer, but is not difficult. Take, for example, the problem of finding the value of M for a flue with a diameter $d = 0·92$ in., carrying 263 lb. of gas per hour, so that the rate of flow is $W/p = 80$ lb. of gas per inch of perimeter per hour. The figures in the tables coming nearest to these values are $d = 0·87$ and $d = 1$ for the diameters, and $W/p = 64$ and $W/p = 90·5$ for the rates of flow. The corresponding values of M are shown below, together with the differences in each direction:

	d=0·87	d=1·00	diff=0·13
W/p=64·0	M=0·0720	M=0·0631	(x) diff= −0·0089
W/p=90·5	M=0·0667	M=0·0583	(y) diff= −0·0084
diff =25·5	(a) diff= −0·0053	(b) diff= −0·0048	

The desired diameter of 0·92 is $\frac{0·05}{0·13} = 0·384$ of the distance between the tabular diameters 0·87 and 1, while the rate of flow of $W/p = 80$ is $16/25·5 = 0·628$ of the distance between the tabular rates $W/p = 64$ and $W/p = 90·5$. The differences being marked a, b, x, and y to distinguish them; the interpolated value of M is found as follows; starting from the value of M for $d = 0·87$ and $W/p = 64$:

$$M = 0·0720 + 0·628 \text{ diff (a)} + 0·384 \text{ diff (x)} + 0·628 \times 0·384 \{\text{diff (a)} - \text{diff (b)}\}$$
$$= 0·0720 - 0·628 \times 0·0053 - 0·384 \times 0·0089 - 0·241 \times 0·0005$$
$$= 0·0720 - 0·00334 - 0·00342 - 0·00012$$

from which

$$M = 0·0651$$

In the following description of the derivation of the formulæ it will be seen that their application to flues larger than 2 in. in diameter is largely a matter of extrapolation. It is thought, however, from the nature of the expressions involved that this can be done with safety, and that the tables will give reasonably accurate results.

III. Experimental and Mathematical Basis of Equations.

A brief review of the methods by which the formulæ were obtained is given below. Further details will be found in the author's paper, Trans. American Soc. Mechanical Engineers, vol. xxxix, 1917, page 709.

The importance, from an engineering standpoint, of the processes of heat transfer between a gas and a flue has led to the carrying out of much experimental work. Each experimenter has varied flue dimensions, rate of flow and gas temperature through comparatively narrow ranges, and in summing up his work has derived formulæ to express the relation between rate of heat transfer and the variables. While such formulæ have been applicable within the restricted range of a single series of experiments, none of them has hitherto been capable of extension to cover the data obtained by other experimenters under other conditions. The present writer had tried to harmonise some of the various groups of experiments, but without success until Hedrick and Fessenden put forward their double logarithmic (lolog) formula (Trans. Am. Soc. Mech. Engrs., vol. xxxviii, 1916, page 407). The use of an expression of the type led to the formulæ which have been given above, which have a much wider range than any previous expressions for heat transfer and harmonise the work of a

considerable number of experimenters working under widely different conditions.

The experiments used are as follows:—

Jordan (Proc. Inst. Mech. E., 1909, page 1317) experimented with heated air passed through water-jacketed copper flues of both circular and annular section. The flue length was 3·28 ft., flue diameters from 0·506 in. to 1·968 in., rate of flow from 30 lb. to 620 lb. per hour, and inlet temperatures from 238 deg. to 750 deg. F.

Nusselt used a flue 0·868 in. in diameter surrounded by a steam jacket, and measured the rise in gas temperature in lengths of from 0·64 ft. to 3·70 ft. when CO_2 illuminating gas, and air at atmospheric pressure, and also at a pressure of 140 lb. per square inch, were admitted at room temperature, the rate of flow varying from 1 lb. to 420 lb. per hour.

Josse with a steam-jacketed flue, 0·905 in. in diameter, experimented along the same lines as Nusselt, using air at pressures of 1·5 lb. per square inch absolute, and at atmospheric pressure, with flow rates from 0·5 lb. to 71 lb. per hour.

Babcock and Wilcox Company and Fessenden experimented independently with water-jacketed flues with diameters from 0·816 in. to 2 in. The gas was produced by combustion and entered at the temperature of the combustion (1,473 deg. to 2,340 deg. F.), the rate of flow varying between 40 lb. and 313 lb. per hour. The Babcock and Wilcox experiments cover both circular and annular section flues.

Boiler Tests.—In addition to the foregoing data obtained with special experimental apparatus, the author has analysed five series of boiler tests. Two of these were made by the Pennsylvania Railroad with locomotive boilers having flues respectively 2 in. and 1·75 in. in diameter. The other three are for stationary boilers, one by Nicholson on an experimental plug-type boiler, having an effective flue diameter of 3 in., the second a series made by the Bureau of Mines on a Heine boiler, with an effective flue diameter of 5·9 in., as described in their Bulletin No. 23, while the third is based on general results obtainable with a return flue boiler with an effective flue diameter of 3·73 in.

In analysing this diversified mass of experimental data which takes in more than 200 individual tests, the first step was to calculate for each test the value of the coefficient M in equation (1):

$$\log T_1/t - \log T_2/t = Mx \quad . \quad . \quad (1)$$

This is done by inserting the measured values for T_1, the initial gas temperature, T_2 the final gas temperature, t the mean flue temperature, and x the flue length in feet. It should be noted that all temperatures are measured from absolute zero, the scale used being immaterial as only temperature ratios appear, and that where, as in the Nusselt and Josse experiments, the flue is hotter than the gas, t is greater than T_1 and T_2, and the equation takes the form:

$$\log t/T_1 - \log t/T_2 = Mx \quad . \quad . \quad (1b)$$

The values of M found in each test were plotted against the values of W, the weight of gas flowing through the flue per hour. It was found desirable to plot log M against log W, and the results of this plotting are shown in Figs. 1 to 5. It is very evident that there is a straight line relation between log M and log W of the form $\log M = A - n \log W$, and it is to be noted that in the more accurate experimental work as the Fessenden I., Jordan and Babcock-Wilcox series, the departure of the points from the straight line is the least. When the lines in these plots are examined it is at once evident that they vary from one series of tests to another, both as to slope and position. This is most clearly seen in the Jordan tests, in which five series of tests, with five different flue diameters, are plotted in single group, in Fig. 1. It is seen from this that as the flue diameter is increased the value of M, for a given value of W, decreases, and also that the slope of the line increases. In the Jordan tests two of the series, B and C, were made with flues of annular section, in these, as explained, the "diameter" is the "effective diameter" equal to four times the hydraulic depth. In working out the formulæ, it was found by comparing the tests with annular and circular flues that the best form of equation for expressing the relation between the coefficient M and the rate of gas flow was:

$$\log M = B - n \log W/p \quad . \quad . \quad (2)$$

where W is the weight of gas per flue in pounds per hour, and p is the gas-swept flue perimeter in inches.

It was further found that in this expression the coefficients B and n depend only on the flue diameter (hydraulic depth). To find the relation between these coefficients and the flue diameter the equations to the lines in Figs. 1 to 5 were found, and the values of B and m thus obtained, which are given in the

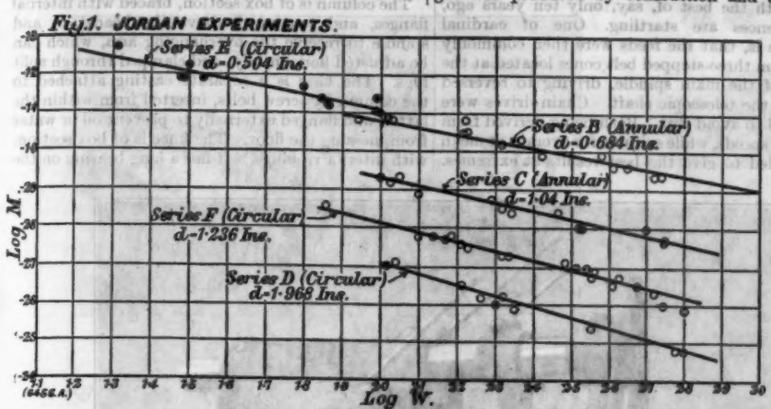
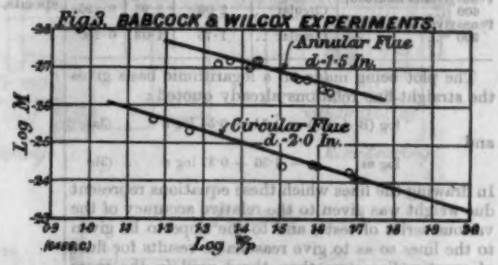
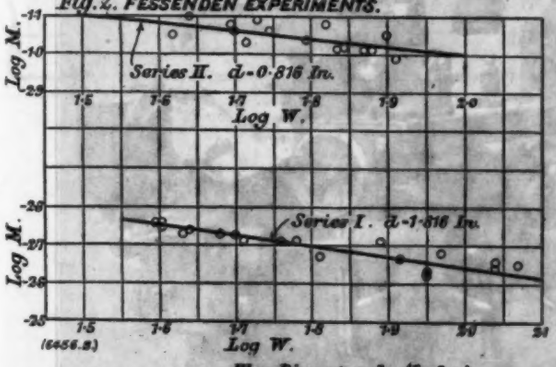
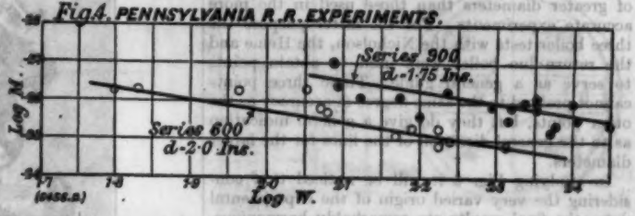
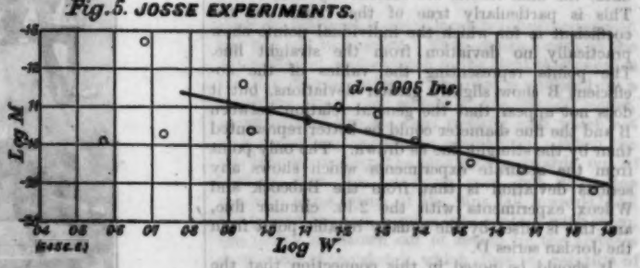


Fig.1. JORDAN EXPERIMENTS.
Series E (Circular) d=0·504 Ins.
Series B (Annular) d=0·664 Ins.
Series C (Annular) d=1·04 Ins.
Series F (Circular) d=1·236 Ins.
Series D (Circular) d=1·968 Ins.
Log M.
Log W.









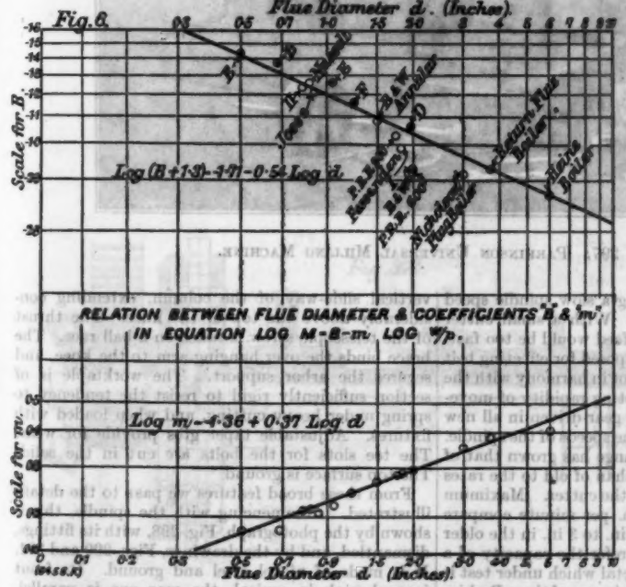


Fig.6.
Flue Diameter d. (Inches).
Scale for B.
Log (B+1·3)=1·7-0·5 Log d.
RELATION BETWEEN FLUE DIAMETER & COEFFICIENTS 'B' & 'm' IN EQUATION LOG M=B-m LOG W/p.
Log m=-1·36+0·37 Log d.
Scale for m.
Flue Diameter d. (Inches).

following table, were plotted over flue diameters as abscissæ, in Fig. 6:—

Test Series.	Flue Section.	Effective Diameter. d	Coefficients. B	Coefficients. m
		in.		
Jordan, E	Circular	0·504	1·43	0·173
Jordan, B	Annular	0·634	1·38	0·180
Jordan, C	Annular	1·040	1·26	0·220
Jordan, F	Circular	1·236	1·16	0·246
Jordan, D	Circular	1·908	1·04	0·295
Essenden I	Circular	1·816	2·99	0·282
Fessenden II	Circular	0·816	1·23	0·212
Babcock and Wilcox	Circular	2·00	2·92	0·295
Babcock and Wilcox	Annular	1·50	1·09	0·265
Nusselt	Circular	0·868	1·25	0·215
Josse	Circular	0·905	1·21	0·205
Pennsylvania Railroad, 600	Circular	2·00	2·93	0·295
Pennsylvania Railroad, 900	Circular	1·75	1·03	0·280

The plot being made on a logarithmic basis gives the straight-line relations already quoted:

$$\log (B + 1·3) = \bar{1}·71 - 0·54 \log d \quad . \quad (3a)$$

and

$$\log m = \bar{1}·36 + 0·37 \log d \quad . \quad (3b)$$

In drawing the lines which these equations represent due weight was given to the relative accuracy of the various series of tests, and to the slope to be given to the lines so as to give reasonable results for flues of greater diameters than those used in the more accurate experiments. For the latter purpose the three boiler tests with the Nicholson, the Heine and the return-flue boiler were used to obtain points to serve as a general guide. These three points cannot pretend to the same degree of accuracy as the other points, but they do give a general indication as to the general direction of the lines for the larger diameters.

In studying Fig. 6 it will be noticed that considering the very varied origin of the experimental data, the final results are remarkably harmonious. This is particularly true of the values for the coefficient m for which the individual points show practically no deviation from the straight line. The points representing the values of the coefficient B show slightly greater deviations, but it does not appear that the general relation between B and the flue diameter could be better represented than by the straight line as drawn. The only point from the accurate experiments which shows any serious deviation is that from the Babcock and Wilcox experiments with the 2-in. circular flue, and this is offset by the equally reliable point from the Jordan series D.

It should be noted in this connection that the coefficient B establishes the rate of heat transfer for a given rate of gas flow, and that the coefficient m measures the extent to which this rate of transfer is affected by a change in the rate of gas flow. The plots for the values of the two coefficients (Fig. 6) suggest that the variation in rate of heat transfer with the variation in rate of gas flow is an extremely stable relation, and is very closely represented by the line in Fig. 6 corresponding to equation (3b), while the basic rate of heat transfer, coefficient B, is subject to incidental variations from one series of experiments to another, the average values, however, being well represented by equation (3a).

The various equations that have been given may require some modifications as further data are accumulated, but it is believed that they represent a long step forward in the direction of establishing exact knowledge of the laws governing the transfer of heat between a flowing gas and the containing flue.

RECENT MACHINE TOOL DEVELOPMENTS.—No. XV.

By Joseph Horner.

Following the illustrations that have been given in previous articles of developments in the elements of machines, it is now proposed to make an eclectic selection of recent tools which may be regarded as generally typical of the trend of present-day design. It will not be convenient, because of inevitable delays that arise in collecting suitable drawings, to illustrate in regular series, classified groups, but instead, selections will be made from miscellaneous examples, as happens to be most convenient. Our recent remarks on the spindles of milling machines, and of the framings and bracings of pillar and knee machines, may be suitably associated with the views here given of one of the recently improved machines of this class manufactured by Messrs. J. Parkinson and Son, of Shipley.

If we compare the best milling machines of the present with the best of, say, only ten years ago, the differences are startling. One of cardinal importance is, that the feeds were then commonly derived from three-stepped belt cones located at the rear end of the main spindle, driving to reversed pulleys on the telescopic shaft. Chain drives were substituted to avoid slip. Both being derived from the spindle speeds, while suitable for average or mean speeds, failed to give the best results at extremes.

The photograph, Fig. 297, illustrates one of the Parkinson Universal millers, some details of which are shown in the drawings following. The size of this example may be estimated by the following working dimensions. The table has a power-feed of 36 in., a 12-in. power cross feed, and 20 in. is the maximum distance from the top of the table to the centre of the spindle.

The column is of box section, braced with internal flanges, and continued above the headstock and spindle to receive the overhanging arm, which can be adjusted horizontally, and clamped through split lugs. The base is a separate casting attached to the column by screw bolts, inserted from within the latter, and flanged externally to prevent oil or water from messing the floor. The knee is of box section, with interior ribbings. It has a long bearing on the

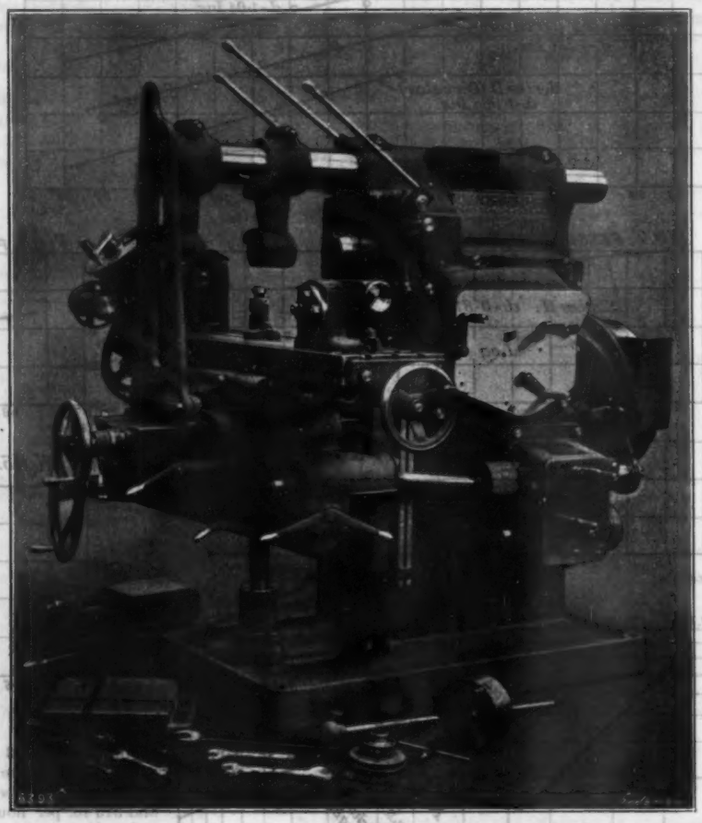


Fig. 297. Parkinson Universal Milling Machine.

vertical slide-way of the column, extending considerably above the top of the knee. The thrust of the telescopic screw is taken on a ball race. The brace binds the over hanging arm to the knee, and secures the arbor support. The worktable is of section sufficiently rigid to resist the tendency to spring under heavy cutting, and when loaded with fixtures. Adjustable taper gibs provide for wear. The tee slots for the bolts are cut in the solid. The top surface is ground.

From these broad features we pass to the details illustrated. Commencing with the spindle, this is shown by the photograph, Fig. 298, with its fittings, dismantled, and by the drawings, Figs. 299 and 301. It is made of nickel steel and ground. Its front journal neck is conical, the rear one is parallel. The hinder bearing is split, to be closed in by the tightening of its nut and its tapered exterior. The front bearing is solid, to take thrust longitudinally. Lubrication is from oil wells, with external drain plugs seen in Fig. 299. The pads may be noticed in the bearings in Fig. 298. The spindle is hollow to receive the bolt that draws in cutter arbors. It has also a large flange, solid, at the nose, shown separately in Fig. 300. A slot is cut across it to receive the hardened steel keys. These afford a

Using a large cutter requiring a slow spindle speed the feed would be too slow. With a small cutter running at a high speed the feed would be too fast. Further, the necessity was imposed for effecting belt changes, a practice which is not in harmony with the views now entertained respecting rapidity of movements. At present feeds are gear-driven in all new machines, independently of the speeds of the spindle. Simultaneously with this change has grown that of giving far more prominence than of old to the rates of feed than of revolutions of the cutter. Maximum rates of from 12 in. to 14 in. per minute compare with maxima of, say, from 2 in. to 3 in. in the older designs. It is also usual to refer the capacity of a machine to the amount of metal which under test it will remove per minute. Thus in one of these Parkinson machines, using a slabbing cutter, on cast-iron, a cut 4 in. wide, $\frac{1}{4}$ in. deep, taken at a feed of 12$\frac{1}{2}$ in. per minute, removed 12$\frac{1}{2}$ cub. in. of metal.

With such a remarkable growth in cutting power, there results the needs of ample driving power, greater stiffness and strength in spindles and framings, involving a remodelling of many details, and the selection of the best grades of constructive materials. Only in broadest outlines, therefore, do the later machines resemble their still recent prototypes.

positive drive to face mills and cutter arbors, which have corresponding slots in their collars, and are made from solid forgings. Large face mills can be attached to the spindle with screws, and should be recessed to fit the flange, and slotted to engage the driving keys.

The cone pulley has steps of large diameters, in contrast with the small steps that have disappeared from these machines, and the lathes. The distributing oil channels for the bearings of the cone are seen in Fig. 298. The locking plunger, Fig. 299, will engage the cone in either one of six positions. Fig. 301, from another machine, shows the disposition of the back gear underneath the cone pulley, an improvement on the earlier method of locating the gear outside, in a horizontal plane with the pulley, derived from the lathe model. Being beneath, it is snugly enclosed and protected by the column. The wheel that is driven by the cone pinion is always running. The pinion on the same shaft that drives the front wheel is slid in and out of mesh by the lever beneath, and seen in the photograph, Fig. 297. On this machine, two rates of back gear speeds are provided, one being in the ratio of 1 : 3·28, the other of 1 : 11·2. A speed index plate, seen in Fig. 297, shows the spindle speeds for each position of belts and gears, corresponding with the locations of levers.

The independently-controlled feeds are a patented feature. They operate automatically, preventing damage in the event of failure of the main drive to the spindle, without interfering with the regular feed control by the trips and automatic stops on the table. The mechanism is shown by Fig. 302.

The gears in the feed-box are driven by the belt pulley to the right, from the countershaft. While the machine is running, the pulley is clutched to the driving wheels in the gear box. When the machine stops, the pulley is automatically declutched from the driving gears, and the feed ceases to operate. The driving shaft, Fig. 302, is hollow, and another shaft goes through it which is not revolved separately but has end movement. This carries a cam at the left-hand end, and a clutch at the right that engages the feed-driving pulley. The cam is enclosed by a revolving drum, in which a number of round, weighted pins are disposed radially, and which act as a centrifugal governing mechanism. When the machine is running, the pins slide outwards, out of contact with the revolving cam, but when the machine stops, some of the pins fall inwards, and the face of the cam coming into contact with them, the pulley is thrown out of action by the endwise movement of the clutch, which stops the rotation of the cam, so that the feed ceases to operate. When the machine is re-started, the pins move outwards, and the clutch is re-engaged by means of the compression spring seen behind the cam.

The feed change gears are assembled in a box as a separate unit, attached to the column. They are contained in the lower box in Fig. 297, shown separately in Fig. 303, and the interior is exposed in Fig. 304. Changes are effected by the movements of levers. The feeds corresponding with those movements are stated in inches per minute on the index plate on top of the box, for a constant speed of revolution of the pulley. For the machine shown in Fig. 297, these are: With pulley revolutions of 210 per minute, 0·50, 0·62, 0·81, 1, 1·22, 1·52, 1·99, 2·46, 3, 3·73, 4·89, 6·05, 7·35, 9·15, 12, 14·80. The gears are of steel, case-hardened, and are automatically lubricated.

In this machine a quick power traverse is provided for the table movement. The pulley, driven direct from the countershaft is flanked on one side with a small pulley that drives the feed, and on the other with a larger one that drives to the quick return at a higher speed, driving a smaller pulley running freely upon the last motion shaft in the gear-box, which during cutting is clutched to the feed gears. This is declutched when the lever for quick traverse is operated, and connection is made to the fast-running grooved pulley that accelerates the shaft, and thus speeds up the traverse of the table.

When a countershaft is used, this is a self-contained box unit, bolted overhead. It is driven at one end from the line shaft, and drives at the opposite end from a stepped cone pulley to the cones in Figs. 296

FIG. 296.

Fig. 299.

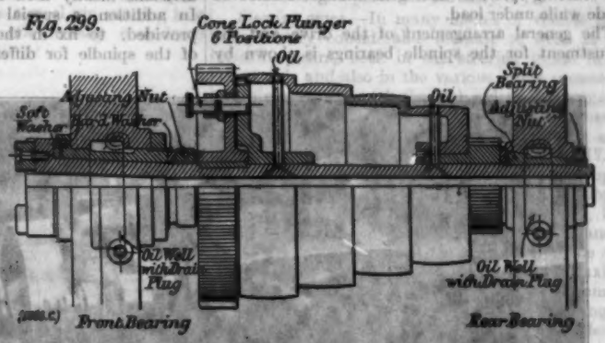


Fig. 301.

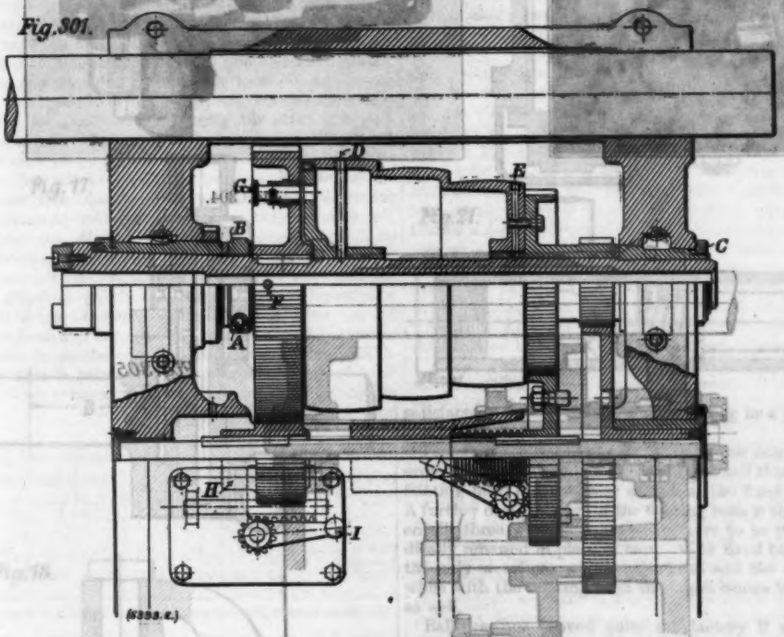


Fig. 300.

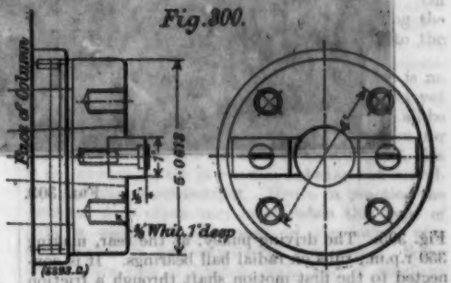
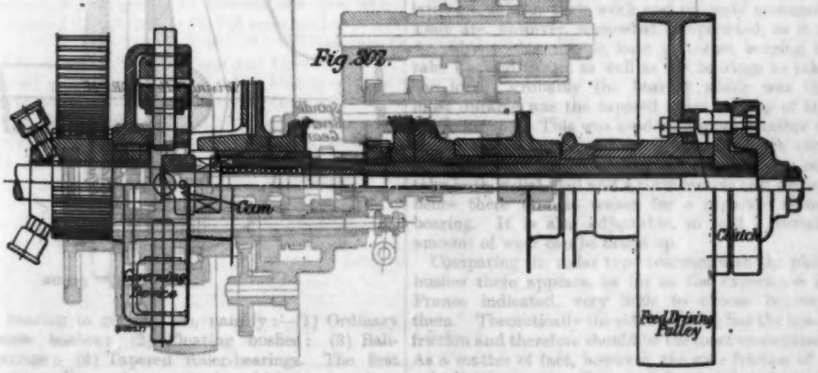


Fig. 302.



or 301. Enclosed in the box are speed-change gears, to give two rates of speed to the cone pulley in a forward direction, and one rate in the reverse direction, so that the spindle can be driven clockwise, or the opposite way. The countershaft also drives continuously the belt for the independent feed. The gear-change control is interlocked with the starting lever, so that gear changes cannot be made while under load.

The general arrangement of the drive, and the adjustment for the spindle bearings is shown by

Fig. 303.

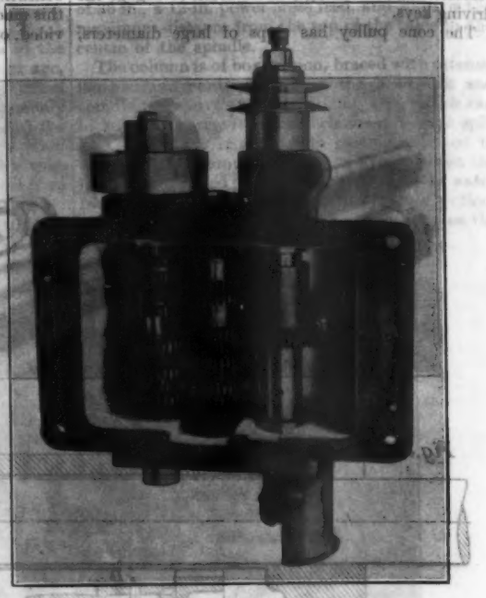


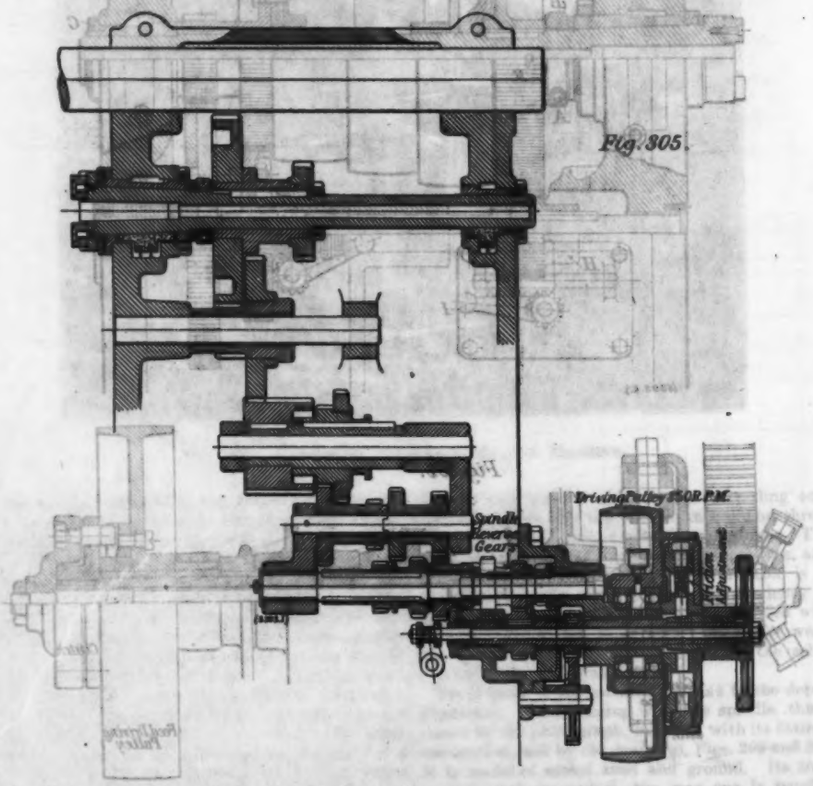
Fig. 304.

Fig. 305. The driving pulley, at the rear, making 350 r.p.m., runs on radial ball bearings. It is connected to the first motion shaft through a friction clutch, with means of adjustment, and is operated by a lever within easy reach of the attendant at the front of the machine. When this is disengaged the driving pulley is the only element in motion. The first motion shaft, and gears for reversing the direction of rotation of the spindle are self-contained in a bracket attached to the column, and the pull of the belt is taken by the bracket. The space between this and the machine spindle is occupied with the sliding gears below, and loosely-running transmission gears above, these being on a fixed shaft, and free from torsional strains. The bosses for the shaft are cast solidly with the column. The spindle gear is the largest that the overarm will admit. The smaller gears are made of a heat-treated steel, and the larger of a high-tensile steel. The teeth are cut with a 20 deg. pressure angle, which, avoiding undercut, increases their strength. A reservoir for oil is arranged within the base of the column, and a pump is fitted driven from the first-motion shaft, that lifts the oil and sprays it over the gears in the column. The arrangements for the lubrication of the main spindle are shown in Fig. 299.

These machines are modified in design for one of three methods of driving, which of course makes no difference in the work-carrying elements, the table, the slides, the knee, the dividing heads. If driven electrically the motor is mounted on a platform provided on the top of the column. The motor is of constant speed, and drives to a pulley below with a belt having provision for adjusting the tension. Or, the drive may be from the main line shafting to the single pulley, the drive in each case being that of Fig. 305. This avoids the use of a countershaft, speed changes being effected by the gears, lever operated, and the machine being started and stopped by the friction clutch. The feed changes are independent of spindle speeds. The full power of the driving belt is always available.

A glance at the photograph, Fig. 297, will show how conveniently hand wheels and levers are disposed within reach of the operator. The dials for the various hand wheels are graduated to read in 1/1,000 in.

The fittings and accessories are characteristic of the requirements of a modern machine. The Universal dividing head has a spindle range from 10 deg. below the horizontal to 30 deg. beyond the perpendicular for cutting bevel and mitre gears. An index plate with holes on both sides is carried directly on the worm shaft, so that dividing is direct without having to pass through gears. All divisions can thus be obtained up to 60, all even numbers and those divisible by 5 up to 120, and divisions mostly used up to 400. In addition, a special mandrel is provided, to fix in the rear end of the spindle for differential indexing. Change gears, and quadrant plates are provided for gearing up from the table screw to the change wheel stud on the dividing head when cutting spirals. A range of arbors both for edge and face mills is provided. Vices with plain and with swivel bases are supplied. There is a vertical spindle milling attachment, and a universal angular attachment. Rotary tables are provided to be mounted on the work table, rotated by hand through worm gear, for use with the vertical spindle attachments for milling circles, circular slots, and combinations of circles with straight lines. The rims of the tables are graduated in degrees, and a large size of table, 18 in. can be fitted with a chain-driven power feed. Attachments for rack-cutting, for cam milling and fixtures for milling flats, squares and hexagons, enlarge the utilities of these machines.



Electrification of the Ofoten Railway.—The Norwegian Storthing has sanctioned the electrification of the Ofoten Railway, that is the Norwegian section of the railway for iron ore transport from Riksgränsen to Narvik, in continuation of the Swedish section of the Gellivare-Riksgränsen Railway, which has already been electrified. An additional agreement has been arrived at with the Sncesvaara-Kirunavaara Iron Ore Company.

DEFECTS IN MOTOR VEHICLES AND THEIR REMEDY.

By F. Strickland.

(*Continued from page* 204.)

Wheel bearings.—For the ordinary touring cars the ball-bearing was far the most common form and worked excellently if well designed in detail. For the lorries, on the other hand, there were four types

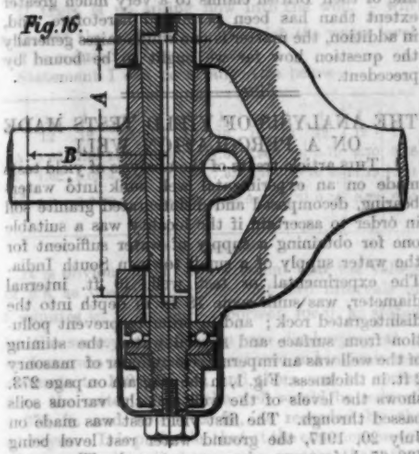


Fig. 16.

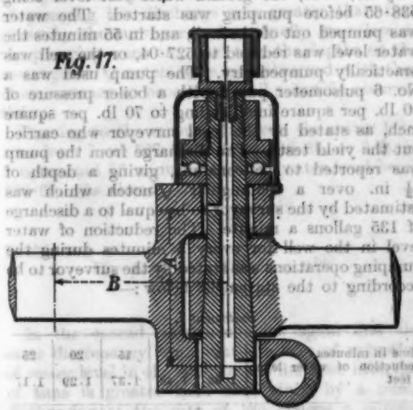


Fig. 17.

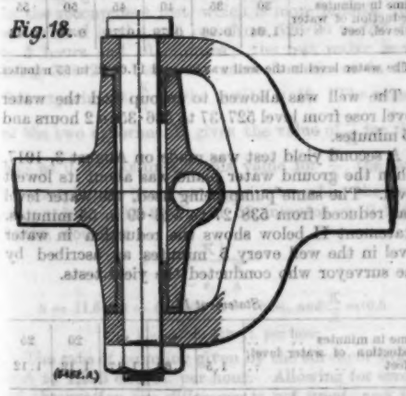


Fig. 18.

of bearing in general use, namely:—(1) Ordinary bronze bushes; (2) Floating bushes; (3) Ball-bearings; (4) Tapered roller-bearings. The first is the ordinary bronze bush, which was made a driving fit in the wheel and ran on a steel axle. This worked quite satisfactorily and proved very durable and cheap to renew. It appears to be desirable that the bush should not be too thin and that it should be a good driving fit in the wheel, following in this way the practice which has been found most satisfactory in other branches of engineering.

The second type is that which was adopted by the War Office as the standard on the subsidy type vehicles and appeared to be very inferior to the first. In place of the bush being a tight fit in the wheel, it is a working fit in both the wheel centre and on the axle. The effect of this is that the bronze bush has both an internal wearing surface and also an external one. It is therefore a distinct variation of ordinary engineering practice where bronze is seldom used as an external wearing surface. Thus it is quite usual in engineering to use a steel pin running in a bronze bush, but it is not usually considered

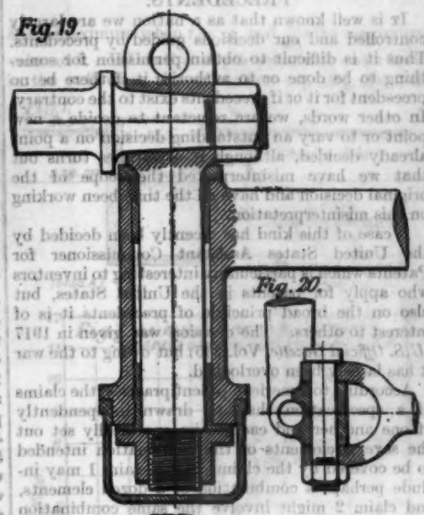


Fig. 19.

Fig. 20.

Fig. 21.

satisfactory to use a bronze pin running in a steel bush.

Experience seemed to show that in this case the ordinary engineering practice was right and that the floating bush did not wear as well as the fixed one. A further disadvantage of the floating bush is that it entails three wearing parts which have to be periodically renewed in place of two. With fixed bushes the only wearing parts are the bush and the axle, while with the floating bush the wheel centre wears as well.

Ball-bearings proved quite satisfactory if made large enough for their work and properly arranged. They are, however, somewhat complicated, as it is desirable to have some form of thrust bearing to take the end thrust as well as the bearings to take the load. Probably the bearing which was the most durable was the tapered roller bearing of the Timken type. This was used on a great number of the American lorries and stood up to its work very well indeed. Being a tapered bearing it can take both radial load and a considerable end thrust, hence there was no reason for a separate thrust bearing. It is also adjustable, so that a certain amount of wear can be taken up.

Comparing the roller type bearings with the plain bushes there appears, as far as the experience in France indicated, very little to choose between them. Theoretically the roller bearing has the lower friction and therefore should be the most economical. As a matter of fact, however, the axle friction of a vehicle is a very small part of the total resistance, so that even if the percentage saving in friction is considerable the total reduction in power required is very small. On the other hand, the roller or ball-bearing is very considerably heavier if carried out on such a scale as to be durable. This extra weight means greater resistance up hill, greater tyre, wear, &c. The plain bush is considerably the cheaper in first cost and renewal and is probably, therefore, the cheapest in upkeep.

Lubrication of wheel bearings.—The ball and roller-type bearings have the advantage that they require no lubrication, and this may be the deciding factor in settling which type should come into general use. The plain bearings, on the other hand, were either lubricated with oil or grease. Of these the oil appeared to be much the best, as the grease often failed to spread properly along the bearing and in that case parts ran partially dry.

Steering gears.—In many makes of vehicle there was a very considerable amount of wear in the steering gears, both in the steering joints in the front axle and also in the various joints connecting the steering-gear with the stub axles. The majority of vehicles both heavy and light, had the steering swivel carried in a jaw, either in the axle as in Figs. 16 and 18 or in the stub-axle as in Fig. 17. In the light cars the English makers usually adopted the Fig. 17 pattern, while the Americans adopted that shown in Figs. 16 or 18. In the lorries, both types were used freely by English and Americans.

At first sight it would appear that it made very little difference whether the jaw was on the axle or the stub-axle, but a careful consideration seems to show that there are great advantages in having the jaw on the axle as in Fig. 16. If we consider the load on the bushes we see that it varies practically inversely as their vertical distance apart A. On the other hand, it is increased by increasing the distance from the centre of the swivel pin to the wheel track B.

With the jaw type of axle, Fig. 16, there is no difficulty in making the distance A great and yet making the jaw of sufficient strength, as it can all be made of H section, and there is ample room for depth. With the jaw in the stub-axle, Fig. 17, this is not so easy, as the jaw comes between the swivel-pin and the wheel-bearing. Hence in practice the distance A is often very small when this type of axle is used, and the wear of the swivel pins and bushes is proportionately very rapid. Some well-known cars of English make and of excellent reputation required these parts to be renewed every six months. This should be quite unnecessary.

Where the jaw is on the axle the pin may either be fixed in the stub-axle and the bushes be in the jaws as Fig. 16, or the pin may be fixed in the jaw as Fig. 18. The former seems distinctly the better, as it is not easy to so fix the pin in the jaws that it does not get loose. Further, with the bushes in the jaw the distance A is increased and the pressure on the bushes therefore reduced.

A point of some importance in connection with these joints is that in the case of Fig. 16 the stub-axle is a cheaper part to produce than that shown in Fig. 17. This is a matter of some importance, as the stub-axle is liable to get worn, whether plain or roller-bearings are used, and may have to be renewed in consequence.

A type of swivel-pin very seldom used, but which appears to have many theoretical advantages is that shown in Fig. 19. In this type all the wearing parts, including the thrust, can be run in an oil bath and should wear very little. The various parts are also very cheap to produce and therefore to renew, the stub-axle itself being a simple lathe job.

Lubrication of swivel-pins.—It appears to be better to lubricate swivel pins, of the ordinary jaw type, with grease rather than oil, as it is difficult to distribute the latter properly to the two bushes. There should be a substantial greaser with good oil ways to the bushes to ensure this.

Thrust bearings.—In the heavier vehicles the load is usually taken by a ball-bearing, as shown in Figs. 16 and 17, but it is very doubtful whether this is the best method. As the wheels are constantly moving through a very small angle the tendency is to form small pits in the ball-races, and it seems probable that a plain washer properly lubricated is better. One of the large carrying companies is replacing the ball thrusts with plain washers.

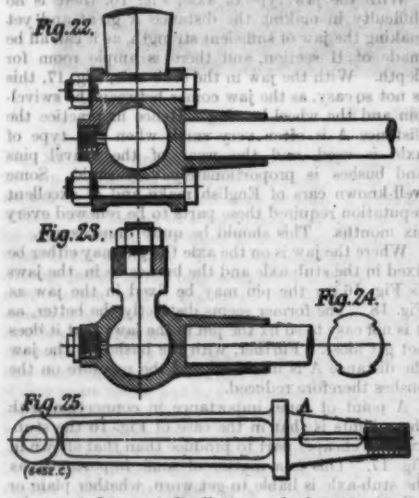
Steering joints.—Although only a small part, the steering joints gave quite a lot of trouble. There are two sets of joints:—(1) Cross-rod joints, *i.e.*, those connecting the two front wheels; (2) Steering-rod joints, *i.e.*, those connecting the steering arm with the front axle. The latter must be universal joints of some kind, but the former may be, and sometimes are, ordinary pin joints. From the point of view

both of production and also of reduction in the number of spare parts, it appears best to make the joints of the cross-rod interchangeable with those of the steering-rod.

There are essentially three forms of steering-joint, namely, the universal pin joint, Fig. 20; the pad-ball joint, Fig. 21; and the ball joint with a split bearing, Figs. 22 and 23. From a mechanical point of view the latter appears to be very distinctly the best. The pin type of joint is difficult to lubricate properly, and it is not easy to fix the pins in the jaws, so that they do not in time get loose. This type is accordingly not very much used. The pad-type, Fig. 21, is used very largely, and is almost universal on European light cars, where, on the whole, it works pretty well. It was not so satisfactory on the lorries.

The great objection to it is that the wearing parts do not completely encircle the ball. Hence it is very difficult to keep lubricant between the surfaces, and with a constant oscillation of the joint round a small arc, the ball gets worn into ridges, somewhat as Fig. 24. If it is allowed to get anything like as bad as shown, the steering-gear may get actually dangerous, as the ridge may get so deep that the ball jams in the pads when the steering is put hard over, in which case it is twisted off. Several accidents occurred from this cause.

The joint of the type of Figs. 22 and 23 is free from the above objections and mechanically is very satisfactory. The ball is totally enclosed, and if



grease is fed in periodically it can be kept free from grit, and thoroughly lubricated. It is therefore very durable, and for commercial vehicles is thoroughly satisfactory. In some cases the joint is split horizontally instead of vertically, the general construction otherwise being the same.

The difficulty in using such a joint for pleasure cars appears to be that the very slightest wear causes it to rattle, and the modern motorist is very particular about small rattles. With the pad type of joint, Fig. 21, the springs prevent this. It seems, however, as if it should be possible to keep the mechanical advantages of the totally enclosed joint and yet avoid the rattle. It is an advantage if the steering balls are so constructed that they can be periodically turned round a quarter of a circle as this greatly prolongs their life. In some cases the joints were cased in leather covers. This is a doubtful advantage, as the covers are not really grease-tight, and the covered-in joints do not get so much attention as those not so covered.

Broken steering-arms.—There was a certain amount of trouble, especially with light cars, with broken steering-arms. As the actual working-stress of the arms is very low these appear to be due solely to cracks caused by vibration. A typical instance is the steering-arm shown in Fig. 25, where a crack formed at A at the end of the keyway and gradually spread through the arm. In this instance the crack was inside the stub-axle; it was not visible unless the steering arm was withdrawn.

In some cases there appears no reason why these arms should crack unless the material was unsuitable. Alloy steels such as appear to have been used will, no doubt, carry higher working stresses than those of lower tensile strength in many positions, but it does not appear to be certain that they are as reliable under constant vibration, and it is even possible that the best results would be got with really good wrought-iron.

(To be continued.)

PRECEDENTS.

It is well known that as a nation we are largely controlled and our decisions guided by precedents. Thus it is difficult to obtain permission for something to be done or to authorise it if there be no precedent for it or if precedents exist to the contrary. In other words, we are reluctant to decide a new point or to vary an outstanding decision on a point already decided, although it sometimes turns out that we have misinterpreted the scope of the original decision and have all the time been working on this misinterpretation.

A case of this kind has recently been decided by the United States Assistant Commissioner for Patents which is particularly interesting to inventors who apply for patents in the United States, but also on the broad principle of precedents it is of interest to others. The decision was given in 1917 (*U.S. Official Gazette*, Vol. 235) but owing to the war it has largely been overlooked.

According to American patent practice, the claims of a specification shall be drawn independently of one another and each claim specifically set out the several elements of the combination intended to be covered by the claim. Thus claim 1 may include perhaps a combination of a dozen elements, and claim 2 might involve the same combination with the addition of one or more elements, and before one can appreciate the scope of such a second claim, one must by a kind of algebraic process separate out the elements of the first claim. The procedure in this country for a similar invention would be to draft claim 2 as a claim to the "combination claimed in claim 1 having in addition" whatever elements it is desired to add so that this would stand out definitely.

Now it appears that although the United States Statute does not specifically state claims must be drafted in the form above referred to, yet as a matter of practice this has been insisted on since 1873 owing to a decision with reference to an application in the name of one Sexton. Recently, however, an applicant, Brown, lodged an application for a patent relating to a special construction of metal car roof in which there was a dominant feature of the fastening of a rigid roof to the car body loosely by way of car line braces. There were in addition two subsidiary inventive ideas each involving a combination of elements. Contrary to the accepted practice, the applicant refused to put his claims in the form of a series of combinations independent of any reference to one another, but put them in what would be understood as British form from the indication given above, because he considered among other things, that that were preferable. The Examiner rejected the application and an appeal was lodged to the Assistant Commissioner.

Some remarks of his are very much to the point in the matter of precedents. He states: "The case is remarkable because in making this rejection the Examiner shows that he makes his ruling by force of precedent and against his convictions. The form of claim would meet with his approval except for the general office practice which has followed the ruling in Sexton since 1873."

He then goes on to deal with the decision in Sexton, and finds that the pertinent part of the decision of 1873 as to the form of claim was in fact an *obiter dictum*. It merely stated that the claim as it originally stood was awkward in form but itself seems to meet the objection by a suggestion as to the interpretation of the claim and the decision did not hold that the second claim, which referred to the first claim, was incomplete, but only that it would be in better form if it were worded independently of the first claim. All claims are assumed to be in one sense complete, but the Assistant Commissioner pointed out that no claim can be so complete as to avoid all reference to anything else to determine its meaning, and that being so, presumably there is no reason why the reference should not be made to another claim as well as to some part of the specification.

The decision concluded with the statement that the form of claim proposed meets the requirements of the United States law, and in the case under consideration clearly points out the invention, so it is well for inventors to know that if they wish they may proceed in the United States on the line of their British claims to a very much greater extent than has been permitted heretofore, and, in addition, the matter is one which raises generally the question how far we ought to be bound by precedent.

THE ANALYSIS OF YIELD TESTS MADE ON A PERCOLATION WELL.

1. This article treats of the analysis of yield tests made on an experimental well sunk into water-bearing, decomposed and disintegrated granite soil in order to ascertain if the locality was a suitable one for obtaining a supply of water sufficient for the water supply of a small town in South India. The experimental or test well, 10 ft. internal diameter, was sunk some 18 ft. in depth into the disintegrated rock; and in order to prevent pollution from surface and subsoil water, the stiming of the well was an impermeable cylinder of masonry 2 ft. in thickness. Fig. 1, in the diagram on page 273, shows the levels of the well and the various soils passed through. The first yield test was made on July 20, 1917, the ground water rest level being 538·65 before pumping was started. The water was pumped out of the well, and in 55 minutes the water level was reduced to 527·04, or the well was practically pumped dry. The pump used was a No. 6 pulsometer pump with a boiler pressure of 80 lb. per square inch, falling to 70 lb. per square inch, as stated by the local surveyor who carried out the yield tests. The discharge from the pump was reported to be constant, giving a depth of 5½ in. over a rectangular V-notch which was estimated by the surveyor to be equal to a discharge of 135 gallons a minute. The reduction of water level in the well for every 5 minutes during the pumping operations was stated by the surveyor to be according to the statement below:—

Statement I.

Time in minutes	5	10	15	20	25
Reduction of water level, feet	1·62	1·46	1·37	1·29	1·17

Time in minutes	30	35	40	45	50	55
Reduction of water level, feet	1·04	0·96	0·79	0·75	0·70	0·48

The water level in the well was lowered 11·61 ft. in 55 minutes.

The well was allowed to recoup and the water level rose from level 527·37 to 536·35 in 2 hours and 55 minutes.

A second yield test was made on August 3, 1917, when the ground water plane was about its lowest level. The same pump being used, the water level was reduced from 538·27 to 526·69 in 55 minutes. Statement II below shows the reduction in water level in the well every 5 minutes as ascribed by the surveyor who conducted the yield tests.

Statement II.

Time in minutes	5	10	15	20	25
Reduction of water level, feet	1·5	1·52	1·17	1·12	1·12

Time in minutes	30	35	40	45	50	55
Reduction of water level, feet	1·08	1·08	0·96	0·92	0·87	0·84

The water level in the well was lowered 11·58 ft. in 55 minutes.

The well was allowed to recoup, and the water level in the well rose from 526·98 to 535·66 in 3 hours and 10 minutes.

2. As shown in a previous article (*vide* page 153 *ante*), if p is the rate of pumping in cubic feet per hour, $\frac{K}{A}$ the specific yield of the water-bearing soil per square foot area of the well under a head of 1 ft. in cubic feet per hour, and A the cross-sectional

area of the well in square feet; and if in any time t hours the water level in the well is reduced h ft.:

$$p\,dt = A\,dh + K\,h\,dt$$

If we have observations showing the reduction of the water level in the well or dh for small intervals of time dt, $\frac{K}{A}$ or the specific yield of the soil can be ascertained, *i.e.*:

$$\frac{K}{A} = \frac{1}{h}\left(\frac{p}{A} - \frac{dh}{dt}\right)$$

If there is no spring flow into the well, $\frac{p}{A}$ will represent the uniform rate at which the water level will be reduced in feet per hour.

Statement I can be arranged as below:

dt	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$
dh	1.62	1.46	1.37	1.29	1.17	1.04	0.96	0.79	0.75	0.70	0.46
h	1.62	3.08	4.45	5.74	6.91	7.95	8.91	9.70	10.45	11.15	11.61
$\frac{K}{A}$*	-1.8	-0.53	0.013	0.18	0.36	0.50	0.56	0.72	0.74	0.73	0.95

* As calculated.

It is obvious from the statement that the values of dh as observed for the first two intervals of 5 minutes w $\frac{1}{12}$ hour are incorrect, for if, as stated by the surveyor, the pump was discharging at a uniform rate of 135 gallons a minute, $w\,h$ in 5 minutes amounts to 108 cub. ft., and there was no spring flow, the water level in the well would be reduced 1·375 ft. and not 1·62 ft., as recorded by the surveyor. It is probable, that at the commencement of pumping the discharge was greater than that given by the surveyor and gradually grew less as the pumping went on; and that the depths on the rectangular V-notch were not observed with that close accuracy so necessary in all scientific observations.

Turning to the recoupment test, the water level rose from level 527·37 to level 536·35, or 9 ft. in 2 hours and 55 minutes, the rest water level being 538·65. As already shown:

$$\frac{K}{A} = \frac{1}{t}\log_e\frac{H}{h}$$

In this case

$$H = 11.28 \quad h = 2.30 \quad t = 2.92$$

$$\therefore \frac{K}{A} = 0.54$$

In the second experiment we again find the same discrepancy, viz., that the rate of reduction of water level in the well for the first two intervals of time is greater than that given by a pump discharging at the rate of 135 gallons a minute. In the recoupment test, which is more reliable, the water level in the well rose from 526·96 to 535·66 in 3 hours and 10 minutes; the rest water level being 538·27. Using the same formula as in the first experiment, $\frac{K}{A}$ works out to 0·46. The mean of the two experiments gives the value of $\frac{K}{A}$ for the soil as 0·5. Assuming this value for $\frac{K}{A}$, the rate of pumping in the first experiment when the well was reduced 11·61 ft. in 55 minutes or 0·9166 hours, would be:

$$p = \frac{K\,h}{1 - e^{-\frac{K}{A}t}}$$

$h = 11.61$, $t = 0.9166$, $A = 78.54$, and $\frac{K}{A} = 0.5$

$\therefore\ p = 1{,}240$ cub. ft. per hour.

The rate of pumping given by the surveyor works out to 1,296 cub. ft. per hour. Allowing for errors of observation the difference is not great, and the calculated rate of discharge is probably the more correct rate of mean discharge of the pump.

The time of total recoupment of the well is given by the formula:

$$t = \frac{A}{K}\log_e\frac{H}{h}$$

By making h very small, say 0·1 for disintegrated granite, H being = 11·29,

$t = 9\frac{1}{2}$ hours.

The time occupied in pumping being taken as 1 hour, the safe yield from the well would be 1,200 cub. ft. in $10\frac{1}{2}$ hours, or the safe yield from the well would be from 2,400 cub. ft. to 2,500 cub. ft. in 24 hours.

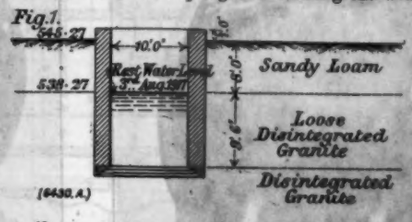
3. In the equation $p\,dt = A\,dh + K\,h\,dt$,

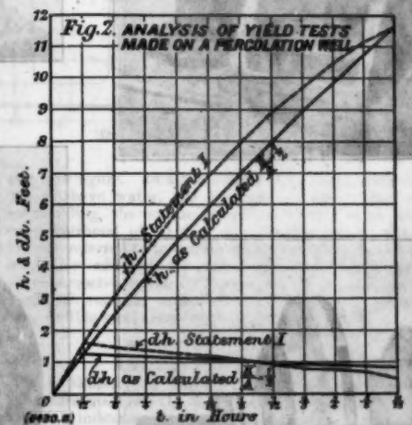
$$dh = \left(\frac{p - K\,h}{A}\right)dt$$

dh is a maximum when $h = 0$, and there is no spring flow entering the well and $dh = 0$ when $p = K\,h$, or when the rate of pumping equals the rate of spring flow and there is no further reduction of water level.

$$h = \frac{p}{k}\left(1 - e^{-\frac{K}{A}t}\right)$$

h is a maximum when $t = \infty$ and $\frac{p}{K}$ is the maximum value of h. If D is that depth below rest water level in the well when the spring flow entering the well





equals the rate of pumping, and no further reduction of water level takes place, the equation above may be written

$$h = D\left(1 - e^{-\frac{K}{A}t}\right)$$

In the case of the well under consideration, assuming $p = 1{,}240$ cub. ft. per hour; and $\frac{K}{A} = \frac{1}{2}$, values of h and dh are calculated for intervals of 5 minutes w $\frac{1}{12}$ hour, and are plotted in the accompanying diagram, Fig. 2, together with the values of h and dh as ascribed by the surveyor, and given in Statement I.

Assuming $\frac{K}{A} = \frac{1}{2}$, it is possible to calculate the rate of pumping for each interval of time of 5 minutes from the reductions in water levels given in Statements I and II.

i.e., $p = A\frac{dh}{dt} + K\,h$

and a wide field is open for checking notch and weir discharges, by pumping from a well, where the specific yield of the soil w $\frac{K}{A}$ has been ascertained by carefully repeated recoupment tests.

The flow of ground water apparently follows laws similar to those governing the flow of heat and of electricity, and there appears to be still a great field open for investigation of the water-yielding capacity of localities of interest both to the agriculturist and the civil engineer. $\frac{K}{A}$ *w*, the specific yield of the water-bearing soil of any area, can be ascertained by sinking pipes of convenient diameter into the water-bearing strata to the required depth, pumping or baling out the water from the bore holes so formed, and noting the time of recoupment to different levels in the pipes.

4. To compare M or the modulus of any soil, or that quantity of water that would be transmitted in a unit of time through a cylinder of the soil one unit in length, one unit cross-sectional area, and under a unit difference of pressure at the ends of and just inside the cylinder, with the specific yield w $\frac{K}{A}$ of the soil in the case of the well under consideration. The discharge into the masonry lined well upwards through the bottom of the well is as already shown:

$$= 2\,M\,h\left\{r\log_e\frac{r}{a} - (r - a)\right\}$$

where M is the modulus of the soil.

In the experimental well under consideration

$$r = 5 + 1 = 6 \text{ ft.} \quad a = 1 \text{ ft.}$$

$$\therefore\ 2\left\{r\log_e\frac{r}{a} - (r - a)\right\} = 11.5$$

and the discharge $= 11.5\,M\,h$ for any static head h. The discharge is also $= K\,h$.

$$\therefore\ 11.5\,M\,h = K\,h = \frac{K}{A}h \times A$$

$$A = 78.54$$

$$\therefore\ M = 6.8\,\frac{K}{A}$$

or nearly $7\,\frac{K}{A}$.

THE HEAT TREATMENT OF STEEL.

In a paper recently read before the Detroit Convention of the American Gear Manufacturers' Association, Mr. G. W. Yale advocated the use of the electric furnace for the heat treatment of steel. A lead bath or an ordinary coal or gas fuel furnace has, he observes, a very great heat capacity, and is accordingly but little cooled down when the material to be heated is placed in it. The consequence is that small parts heat up more quickly than large ones and the result is often disastrous. He considers for example, the case of a "chunk" of steel 4 in. in diam., with a spur $\frac{1}{4}$ in. thick which is put into a big furnace or lead bath at a temperature of 1,500 deg. F. The bath or furnace is chilled but slightly, and the spur being small in volume heats up rapidly and gives a large grain structure, whilst the heavier portion becomes heated more slowly.

Steel expands when heated, both when the temperature is below and when it is above the transformation point, but at the actual transformation point it contracts, and hence if different portions of a mass of steel under treatment pass the transformation point at different times, distortions are likely to occur, and there may be cracking and failures.

If the same piece of steel be heated in an electric furnace of small heat capacity, the furnace is chilled when the steel is placed in it and the temperature can then be raised slowly, in which case both light and heavy portions of the article under treatment pass through the transformation point at the same time.

Although the cost of electric heating per B.Th.U. developed, is much higher than in direct heating by coal, gas or oil, the cost per B.Th.U. usefully employed is not very different, since, with electric heating, the heat is generated just where required, whilst with other systems of heating 60 per cent. to 80 per cent. of the total heat passes off up the chimney. The labour costs are also markedly different since with direct heating, the total cost of the labour includes that expended in cleaning off scale, straightening warped pieces, or grinding operations, which are said to be unnecessary when the heat treatment is conducted along the lines which Mr. Yale advocates. Taking the case of such articles as automobile gears, it is stated that two men can, with the electrical method, turn out 2,000 lb. and 2,400 lb. of treated metal per day.

FUEL CONSUMPTION TRIALS OF MOTOR CARS.—We are informed that the competitors who took part in the Basle (Switzerland) fuel consumption trials held recently, were about 40 in number, with cars of French, Swiss, Italian, American and English construction. The cars were divided into teams and the awards based on the lowest consumption of the team. The best team average is said to have been 6·35 litres per ton and per 100 km., and the most economical car in this team is claimed as being a four-cylinder Fiat of 65 mm. bore by 110 mm. stroke. This car, one of the new Fiat type, carried four passengers for a distance of 97 miles, and the fuel consumption is given as 8·85 litres per 100 km., or about 32 miles to the Imperial gallon.

SUBMERSIBLE ELECTRIC MOTOR PUMP.

MR. T. L. REED COOPER, ENGINEER, WESTMINSTER, LONDON, S.W.1.

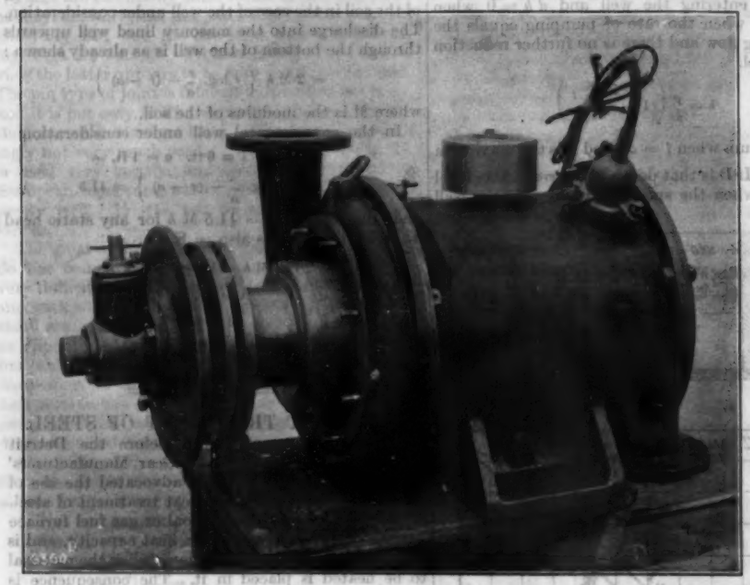


Fig. 1.

Fig. 2.

Fig. 4.

Fig. 3.

We recently had an opportunity of inspecting a new combined electric motor and centrifugal pump designed by Mr. T. L. Reed Cooper, 11 Tothill-street, Westminster, London, S.W. 1, and intended especially for working submerged in connection with marine salvage operations, pumping out ships' bilges or flooded mines, and for any other similar purposes in which it may be convenient to employ a pump capable of working "drowned." The pump will, however, work equally well above water, so that it also forms a particularly neat, compact and easily portable unit for ordinary pumping work wherever alternating current power supply is available for running it.

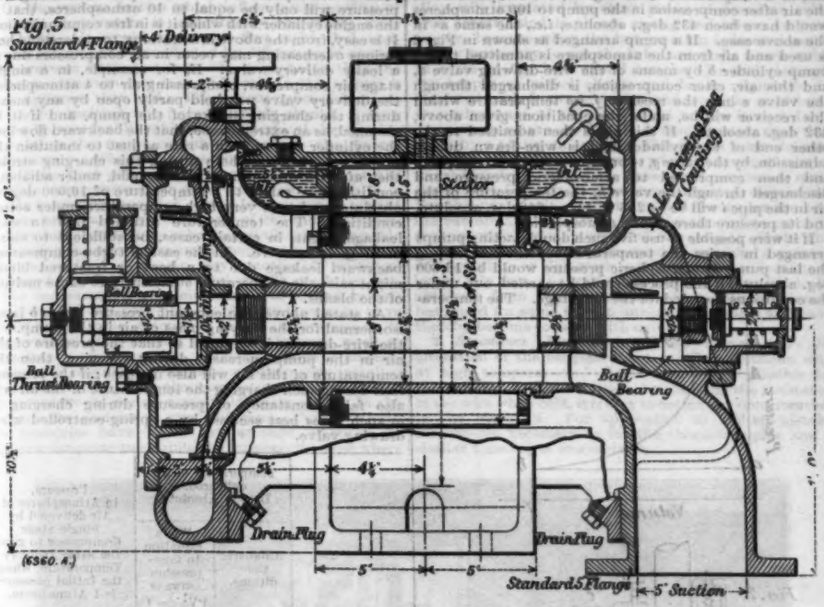
Several interesting and novel features are included in the design of the pump, which is shown complete, but with the rotating parts partially removed, in Fig. 1, above. The design, however, will be best understood from an inspection of the longitudinal section Fig. 5, on the opposite page. It should first be explained that the pump comprises a three-phase induction motor having a squirrel-cage rotor, to one end of which the pump impeller is attached, while the volute chamber and delivery connection are formed in the end cover. The suction connection is formed in the other end cover, and the water passes in a longitudinal direction through helical passages in the rotor to the impeller, as will be clear from the engraving, Fig. 5; the main dimensions of the pump are also given in this illustration. The most important feature of the design is the method employed for preventing water from reaching the stator windings and laminations, which, for this purpose, are contained in a closed annular chamber practically filled with transformer oil. It will be remembered that in other motors of this type water is allowed free access to the stator windings, which must therefore be insulated with rubber. Rubber insulation is, however, comparatively bulky, so that large slots are necessary to contain a given number of conductors, and, consequently, the stator teeth between the slots must be made narrow. This is objectionable electrically because of the high flux density produced, which is rapidly increased by the corrosion of the laminations; corrosion also renders frequent renewals necessary in some cases. In Mr. Cooper's motor the insulation of the stator windings is of cotton, as in an ordinary induction motor, so that the slots can be made of the usual dimensions, and corrosion of the stator laminations is completely avoided by the fact that they are immersed in oil. This feature of the design also enables high voltages to be used directly in the stator windings, and has the additional advantage of readily conducting the heat from the latter to the casing and thence to the surrounding water when the motor is working submerged.

The formation of a closed chamber round the stator windings was, however, a rather more difficult matter than would appear at first sight. For efficient working it is necessary to keep the air gap between the stator and rotor as small as possible, so that as one of the walls of the chamber must come in the air gap, a material having a high magnetic permeability must be employed. The use of ordinary sheet iron or steel for the purpose would, however, be inadmissible owing to the corrosive action of the impure water with which it would come into contact. The rotating field from the stator also gives rise to eddy currents in the material in the air gap, and as these, *ceteris paribus*, will be proportional to the conductivity of the material, the latter property should be low, to avoid heating effects and losses due to this cause. Experiments were made with many different materials in an endeavour to select one having the desired combination of high permeability, low conductivity, and resistance to corrosion, and a special steel alloy was eventually obtained having the desired properties, so that the efficiency of the immersible motor is not greatly inferior to that of an ordinary squirrel-cage motor having the same output. The special alloy is in the form of a thin cylinder in close contact with the stator laminations and surrounding the rotor with the necessary running clearance. It is secured by flanged rings screwed to the yoke at each end, as will be understood from Fig. 5. The half-tone engravings, Figs. 2 and 3, respectively, show the stator before and after the casing has been placed in position. To allow for the expansion of the oil in the chamber a flexible steel diaphragm was fitted in one of the flange rings supporting the chamber, as shown on the right in Fig. 5, but this device was found to be of insufficient capacity, and the air vessel shown in most of our illustrations was accordingly added. This, however, is a temporary arrangement only, and it will be replaced in later designs by an air pocket formed in the yoke casting so as to avoid projections as far as possible.

SUBMERSIBLE ELECTRIC MOTOR PUMP.

DESIGNED BY MR. T. L. REED COOPER, ENGINEER, WESTMINSTER, LONDON, S.W.1.

Fig. 5.



An air vessel such as that shown would, obviously, be an undesirable feature on a pump intended for rough usage.

In the rotor no attempt is made to prevent the water from reaching the laminations since there is no difficulty in insulating the conductors, which are solid copper rods, and the effects of corrosion, if it should occur, are much less serious than is the case with the stator; the water, in fact, has the useful effect of keeping the rotor quite cool. The rotor shaft is carried by a plain ball bearing at the suction end, and in a combined ball thrust and radial bearing at the impeller end. Both bearings are completely enclosed in boxes filled with grease compressed by spring plungers, the stems of which protrude through the box covers and thus serve to indicate when the supply of grease needs to be replenished. The thrust bearing at the impeller end is mounted in an end cover attached to the volute chamber casting by means of studs, and a feature of considerable practical importance in the design of the pump is that the whole of the rotating parts, including both bearings, can be withdrawn bodily, without disturbing the pipe connections, by removing the nuts from the studs holding the cover in position and taking off a ring nut at the suction end shown in Fig. 5. It is thus an extremely simple matter to inspect the rotor and bearings or to clean the water passages when necessary, although the bearings can be examined without taking out the rotor if desired. Fig. 1 illustrates the operation of removing the rotating parts, and Fig. 4 shows the rotor, impeller and bearings completely withdrawn from the stator. Fig. 1 also shows the watertight plug and socket connection for the electric mains. The latter terminate in three pins in a hemispherical flanged casting, the three pins fitting into corresponding sockets carried by an insulating block in the yoke casting, and shown in Figs. 2 and 3. The two parts are held together by three swinging bolts, and a watertight joint is made by means of a rubber ring.

The pump illustrated weighs 8¼ cwt. in working order, with oil in the chamber. It is fitted with 5-in. suction and 4-in. delivery connections, and its capacity is given as 370 gallons per minute, or 100 tons per hour, against a head of 75 ft.; smaller and larger sizes can, however, be made with capacities ranging from 50 tons to 350 tons per hour at the same head. The maximum overall efficiency claimed is about 44 per cent., which, considering the special design of the motor, and the fact that the figure includes the efficiency of a comparatively small centrifugal pump, seems to be a fairly reasonable figure. We have ourselves witnessed a test in which the above-mentioned figure for overall efficiency was approximately reached when the pump illustrated was delivering 120 tons per hour against a head of 83 ft. There is, of course, no difficulty in keeping the motor cool for an indefinite period when it is running submerged, and, when working above water, the cooling effect of the water passing through the rotor and end covers is sufficient to reduce the temperature rise to a very low figure. In a 5-hour run at full load, with the pump above water, the temperature rise in the oil surrounding the stator windings would be in the neighbourhood of 30 deg. F. Another point, which may be referred to in conclusion, is that the pump can be easily adapted for handling weak acids and other corrosive liquids by forming the casing and pump parts of suitable materials and using the special incorrodible steel alloy for the rotor laminations.

INDUSTRIAL NOTES.

THE Ministry of Labour state that employment continued good, on the whole, in July. In the cotton weaving industry, the linen industry, the fancy lace trade, and the boot and shoe industry, however, it was slack, and in some other industries there was a slight decline from the high level of previous months. The percentage unemployed among workpeople (skilled and unskilled) covered by the Unemployment Insurance Acts was 2·73 on July 30, as compared with 2·62 on June 25, and the percentage unemployed amongst members of certain trade unions (mainly of skilled workpeople) from which statistics are obtained was 1·4, as compared with 1·2 in June and 2·0 in July, 1919. The number of men and women on the live registers of the Employment Exchanges was 271,504 at July 30, as compared with 287,003 at June 25.

The number of trade disputes involving stoppages of work, reported to the department as beginning in July, was 147. In addition, 118 disputes which began before July were still in progress at the beginning of the month. The total number of workpeople involved in these disputes (including those thrown out of work at the establishments where the disputes occurred, though not actually on strike) was over 90,000, as compared with about 128,000 in the previous month, and about 839,000 in July, 1919. The estimated aggregate duration of all disputes during the month was about 908,000 working days, as compared with about 1,257,000 days in June, 1920, and 8,018,000 in July, 1919, when disputes were in progress in the cotton and coal-mining industries, involving large numbers of workpeople.

In the industries for which statistics are available, changes in rates of wages reported to the department as having been arranged to come into operation in July resulted in a total increase of nearly 200,000*l.* a week in the wages of nearly 500,000 workpeople. The principal bodies of workpeople affected were building trade operatives in Scotland, tin-plate workers in South Wales and Monmouthshire, flour-mill workers generally and workers employed at gas undertakings. The changes in hours of labour affected over 11,000 workpeople and resulted in an average decrease of nearly 2¼ hours in their weekly working time.

The average level of retail prices (including those of food, clothing, fuel and light, &c., as well as rents), on July 31, as indicated by the statistics prepared by the Ministry of Labour, was about 155 per cent. above the level of July, 1914. For food alone the average increase was 162 per cent. These statistics relate to commodities of pre-war working class consumption and in the calculations the same quantities and, so far as possible, the same qualities are taken at the present time as before the war.

* A conference took place on the 19th inst. between representatives of the National Alliance of Employers and Employed and the Industrial League and Council, as a result of which it was agreed to recommend the amalgamation of these bodies. The joint Executives will meet shortly to consider the report and to work out the details. There will then be created the most influential body of employers and employed which has ever existed in any country. Many leading employers and prominent trade unionists are connected with one or other of the amalgamating bodies, and the main object to be pursued will be the bringing together of Capital and Labour with a view to the avoidance of labour troubles, the joint consideration of matters appertaining to their industries and the general industrial welfare. Such a body will exercise a tremendous influence on the reconstruction problems which are now before the country.

Mr. W. C. Bridgeman, M.P., has been appointed Secretary of Mines, and Major Sir Philip Lloyd-Graeme, K.B.E., M.C., M.P., Parliamentary Secretary to the Board of Trade, in succession to Mr. Bridgeman.

A dispute has occurred between the Electrical Trades Union and Messrs. Cammell, Laird and Co.'s works, Penistone, in connection with the employment of a non-union foreman to which the said union took exception several weeks ago. A number of conferences have been held since between the Engineering and National Employers' Federation and delegates of several unions. The Electrical Trades Union contest the right of employers to employ foremen whether they are trade union members or not, and seek to insist on all foremen over electricians being trade union members, a departure from the practice hitherto observed which the employers consider it essential to resist. The point at issue may lead to a lockout. Meetings were held in London and Manchester last Tuesday, following which a committee has been appointed consisting of two representatives from each of the eight unions whose members would be involved in the event of a lockout occurring in the engineering trade, with instructions immediately to get into touch with the Electrical Trades Union, the Amalgamated Engineering Union and the Iron and Steel Trades Confederation, to submit to them what the attitude of the unions affiliated to the National Federation of General Workers is relative to the threatened lockout.

Captain W. G. Barnfield, the Yorkshire representative of the London Coal Association, and member of the West Yorkshire Anti-Nationalisation Propaganda Committee, speaking last week at Hull, at a meeting of the Humber Coal Exporters, stated that after recent investigations in the West Riding colliery districts, he could say that opinions were divided as to the threatened coal strike except on one point, and that was that the miners did not want to enter upon the struggle. Generally speaking, the men were satisfied with their wages, and did not think it worth while to strike on the chance of getting more. And yet these men, if they were questioned as to their position, would reply, "We shall strike, of course, if our leaders tell us to!" Thus they confessed that they were led by the nose by men who were not honest, because they knew that the miners whom they were urging to strike were getting as much in wages as the product could pay. The truth was that these advisers were out for revolution. He believed that a coal strike was bound to fail, because the moment a strike was entered upon the source of profit and of wages was stopped, and profits on exports ceased. He urged the traders of Hull to use every effort to assist the propaganda which he was conducting, and so help to thwart the efforts of the agitators who were aiming at revolution and chaos.

Dealing with the coal situation, which transcends all other industrial questions at the present time, the British Commonwealth Union say that the claim of the miners implies that coal-mining should provide about one-quarter of the direct taxation that is borne by other industries (in proportion to number employed) in the form of income-tax, super tax, corporation tax, excess profits duty. In other words, the miners' claim is that other industries should be overtaxed for the purpose of raising their wages. Let us, the British Commonwealth Union adds, examine this claim in the light of the service at present given by the miners to the rest of the nation. On the basis of the output in 1913, the men now engaged, i.e., about 1,210,000, should raise about 313,000,000 tons a year, whereas actually the present rate is about 235,000,000 tons, a decrease of almost exactly 25 per cent. If the miners obtain the increase in wages demanded, their

total wages will be about 315,000,000*l.* a year, or about 260*l.* a year as compared with 82*l.* in 1913, an increase of 217 per cent. as compared with a rise in prices to them of less than 140 per cent. (The increased price of coal does not affect them.) Their standard of living would thus be better by one-third. In other words, the miners are asking one-third more bread, clothes, &c., in return for one-quarter less coal than they gave. Put in another way, they are selling the commodity at a price expressed not in money but in other commodities 80 per cent. higher than in 1913. It is the worst case of profiteering yet revealed. The rank and file of the miners are not the real guilty ones, but the men who are misleading them are entirely blameworthy in the highest degree.

Sir Robert Horne, President of the Board of Trade, having been asked a few days ago whether "the miners have threatened a strike only because the coalowners have refused to stop bleeding the coal consumers," replied: "The coalowners are not directly concerned. They will get the profits they are entitled to under the Coal Mines Emergency Act, and no more. Nobody can yet tell what the profit on the export of coal will be or whether there will be any. That entirely depends on the amount which is produced, and if the miners should carry out their threat to strike it is obvious that the surplus available for export, after our domestic and industrial needs are satisfied, will quickly disappear. But in any case, be the surplus large or small, it will not go to the coalowners, but to the Exchequer. It is money which, in the case of other industries, would be paid as excess profits duty to the Treasury. The suggestion that the miners' action is dictated by a desire to stop the coalowners bleeding the coal consumers is flagrantly inaccurate. I repeat that in no circumstances will the surplus profits which the miners expect, go into the pockets of the coalowners. That must be made clear once for all in order that the public may be in a position to judge the issue rightly." Mr. Austen Chamberlain, Chancellor of the Exchequer, has entirely confirmed the above statement made by Sir Robert Horne.

It is reported that it has been unanimously decided to approve of the principle of amalgamation of shipping trade unions embracing manual and clerical workers. A committee has been appointed to prepare a draft constitution. Mr. H. Gosling, president of the Transport Workers, is chairman of the committee, and Mr. E. Bevin hon. secretary. The unions represented at the meeting at which the decision was arrived at were the following: National Union of Dock Labourers; Dock, Wharf, Riverside and General Workers; Scottish Union of Dockers; National Amalgamated Labourers' Union (Swansea); National Shipping Clerks' Guild (Liverpool); National Union of Dock Wharves and Shipping Staffs (London); Amalgamated Stevedores' Labour Protection League; South Side Labour Protection League (London); Cardiff, Penarth and Barry Coal Trimmers' Union; Amalgamated Society of Watermen, Lightermen and Bargemen (London); Trimmers and Teamers' Association (North of England); Weaver Watermen's Association; National Union of Shipping Clerks and Grain Weighers; Mersey Watermen's Association.

A DYNAMICAL METHOD FOR RAISING GASES TO A HIGH TEMPERATURE WITHOUT THE USE OF HIGH PRESSURES.*

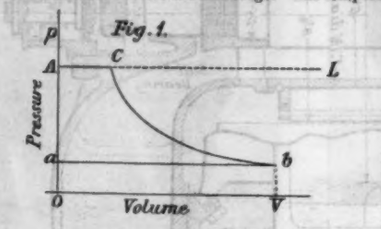
By Professor W. H. Watkinson, Liverpool.

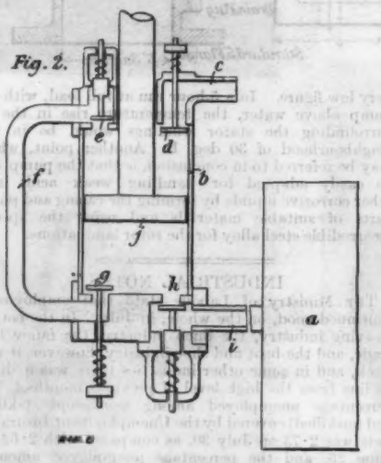
If air be allowed to flow from the atmosphere through a spring-loaded wire-drawing valve adjusted so that the air in the cylinder during the charging stroke is constant at a pressure of one-quarter of an atmosphere, and if this air is subsequently compressed to atmospheric pressure, then, assuming adiabatic and frictionless conditions and neglecting the effect of clearance in the pump cylinder, the absolute temperature of this air at the end of compression will be approximately 1½ times the absolute temperature of the outside atmosphere, that is, T_c, Fig. 1, will be approximately equal to 1½ times 288, that is 432 deg., when the atmospheric temperature is 15 deg. C. The reason for this is that the constant pressure line *a b*, Fig. 1, is approximately an isothermal line for the varying mass of air in the pump cylinder, and the temperature of the air during the charging stroke is approximately the same as that of the outside atmosphere. Some applications of this principle were given in a paper read by the author at the Newcastle meeting of the Association in 1916.† The connection between temperature, pressure and volume of a given mass of gas undergoing expansion or compression is given by the equations:

$$\frac{T_c}{T_b} = \left(\frac{p}{p_b}\right)^{\frac{n-1}{n}} = \left(\frac{V_b}{V_c}\right)^{n-1}.$$

and from these equations it is obvious that the absolute temperature ratio depends on the absolute pressure ratio and not on the magnitudes of those pressures. If, in the above illustration, the air had flowed into the cylinder at a pressure of 25 atmospheres from a receiver in which the air was at a pressure of 100 atmospheres and at a temperature of 15 deg. C., the temperature of the air after compression in the pump to 100 atmospheres would have been 432 deg., absolute, *i.e.*, the same as in the above case. If a pump arranged as shown in Fig. 2 is used and air from the atmosphere is admitted to the pump cylinder *b* by means of the wire-drawing valve *d*, and this air, after compression, is discharged through the valve *e* into the receiver *f*, its temperature within this receiver will be, under the conditions given above, 432 deg. absolute. If this air is then admitted to the other end of the cylinder and is wire-drawn during admission, by the valve *g*, to one-quarter of an atmosphere and then compressed to atmospheric pressure and discharged through the valve *h*, the temperature of the air in the pipe *i* will be = 288 × 1½² = 648 deg. absolute, and its pressure there will be atmospheric.

If it were possible to use five such double-acting pumps arranged in series the temperature of the air leaving the last pump at atmospheric pressure would be 16,600 deg. absolute, if the process could be carried out under the conditions assumed for the first stage. The temperature of the air leaving the second pump would be approximately 1,460 deg. absolute and, with our present materials and present types of compressors, this is probably the upper limit at which the pump could be made to operate.





To obtain the above enormous increase in temperature by single-stage compression would require the pressure-ratio to be about 1,040,000, and if the initial pressure was at one atmosphere the final pressure would have to be 1,040,000 atmospheres.

Assuming that the pressure of the air in the bulb of an incandescent electric lamp is one-millionth of an atmosphere, and that its temperature is 15 deg. C., then if the envelope could be suddenly annihilated the air which initially filled the bulb would be compressed to a pressure 1,000,000 times its initial pressure and, assuming that no mixing took place, it would be raised to a temperature of 16,600 deg. absolute.

The multi-stage wire-drawing method described above might be regarded as a thermo-dynamic ratchet. The accompanying table gives the temperature attained at each stage under the conditions assumed, also the corresponding temperatures at each stage when the equation of the compression curve is $PV^{1\cdot3} = C$. (In this case, for simplicity, no account is taken of heat lost or gained other than during compression.) The corresponding pressures required for single-stage compression, assuming the initial pressure to be one atmosphere, are also given.

One possible application of the principle described above may be indicated. If the pump shown in Fig. 2 be connected to the compression space of the cylinder *a* of an internal-combustion engine, the temperature of the air in the pipe *i* may be raised sufficiently high to effect ignition of fuel or of fuel and air in this pipe. If, for example, the air admitted to the pump cylinder by the valve *d* is wire-drawn to a pressure of half an atmosphere and then compressed to a pressure of 2 atmospheres and discharged through the valve *e* into *f*, where the pressure is 1 atmosphere, and if the process is repeated on the other side of the piston and the air discharged into the pipe *i* at a pressure of 1 atmosphere at the beginning of the compression stroke of the piston of the engine, then the temperature of the air in the pipe *i* will be the same as if this air had been compressed from 1 atmosphere to 16 atmospheres, and if the compression pressure ratio in the engine cylinder is 16, the air in the pipe or pocket *i* will, at the end of the compression stroke of the engine, be at the same temperature as if it had been compressed from 1 atmosphere to 160 atmospheres, although its pressure will only be equal to 10 atmospheres, that in the engine cylinder with which it is in free communication. It is easy, from the above illustrations, to understand how serious overheating may occur in air compressors due to a leaky delivery valve. If, for example, in a single-stage air compressor, compressing air to 4 atmospheres, the delivery valve was held partly open by any means during the charging stroke of the pump, and if it be assumed, as an extreme case, that the backward flow into the cylinder was at such a rate as just to maintain the pressure at 1 atmosphere during this charging stroke, then after 10 revolutions the air would, under adiabatic conditions, be raised to a temperature of 16,600 deg. C. absolute, and to a very high temperature under actual conditions. The temperature attained due to such leakage might, in certain cases, be sufficient to cause melting of the valve. In the case of turbo-compressors, backward leakage due to a bent or fractured blade, might raise the temperature sufficiently to cause melting of the blades.

As stated above, the constant pressure line *a b* is an isothermal for the varying mass of air in the pump. If the wire-drawing is arranged so that the pressure of the air in the pump increases during charging, then the temperature of this air will also increase; if the pressure falls during such charging the temperature of the air will also fall. Constancy of pressure during charging is in such cases best secured by a spring-controlled wire-drawing valve.

	Temperature of Air delivered, Deg. C. Absolute.		Pressure, in Atmospheres of Air delivered by Single-Stage Compressor to give the same Delivery Temperature, when the Initial pressure is 1 Atmosphere.
	Adiabatic Conditions.	When Equation to Compression curve is $PV^{1\cdot3} = C$.	
First pump—			
First stage ..	432	396	4
Second stage..	648	546	16
Second pump—			
First stage ..	972	751	64
Second stage..	1,458	1,033	254
Third pump—			
First stage ..	2,187	1,420	1,016
Second stage..	3,280	1,957	4,064
Fourth pump—			
First stage ..	4,920	2,695	16,254
Second stage..	7,380	3,700	65,016
Fifth pump—			
First stage ..	11,070	5,100	260,064
Second stage..	16,600	7,030	1,040,260

Motor Traffic and Danish Roads.—The Danish authorities are much concerned at the damage done to the roads by the great increase in motor car traffic which occurred during the last two years. There are now some 14,000 motor cars in Denmark (of which about 2,000 are commercial vehicles) besides a similar number of motor cycles, and half of this number have been added during the last two or three years. The expenditure necessary to put the roads into good condition is estimated at 465,000,000 kr.

American Copper Production.—The production of copper in the United States in 1919, says *Commercial America*, was markedly smaller than in 1918, according to preliminary figures and estimates collected by B. S. Butler, of the United States Geological Survey, Department of the Interior, from all plants that make blister copper from domestic ores or that produce refined copper. At an average price of about 19 cents a pound the output for 1919 had a value of $243,000,000, as against $471,000,000 for 1918. The figures showing the smelter production from domestic ores represent the actual output of most of the companies for the first 11 months of the year and the estimated output for December. A few companies gave no figures for November but furnished estimates for the combined output of November and December. The production of blister and Lake copper from domestic ores was 1,278,000,000 lb. in 1919, against 1,908,000,000 lb. in 1918 and 1,224,000,000 lb. in 1913. The supply of refined copper—electrolytic, Lake casting and pig—from primary sources, domestic and foreign, for 1919 is estimated at 1,800,000,000 lb., compared with 2,432,000,000 lb. for 1918 and 1,615,000,000 lb. for 1913. According to the Bureau of Foreign and Domestic Commerce, the imports of copper in all forms for the first 10 months of 1919 amounted to 346,855,000 lb., against 575,000,000 lb. for the 11 months of 1918. The exports of pigs, ingots, bars, plates, sheets, rods, wire and like copper products for the first 11 months of 1919, as determined by the same bureau, amounted to 496,350,000 lb.; the exports for the 12 months of 1918 were 744,429,000 lb. At the beginning of 1919 about 180,000,000 lb. of refined copper was in stock in the United States. Adding this quantity to the refinery output for the year shows that the total available supply of refined copper was about 1,980,000,000 lb. On subtracting from this total the exports for the first 11 months and the estimated exports for the last month, and assuming that there was no change in stocks, it appears that the supply available for domestic consumption in 1919 was considerably less than the 1,661,000,000 lb. available in 1918.

* Paper read before Section G of the British Association for the Advancement of Science, August 25, 1920.

† See Engineering for September 22, 1916.

MEASUREMENT OF CASTING TEMPERATURES IN THE BRASS FOUNDRY.*

By John Arnott.

Of the various factors which influence the quality of castings, temperature is undoubtedly one of the most important. It would appear at first sight that non-ferrous metals are more affected by differences in casting temperatures than cast-iron. It is probable that the difference between cast-iron and brass in this respect is more apparent than real. The various types of furnaces in use for melting non-ferrous metals should, if they are to be reasonably rapid and economical, be capable of heating the metal considerably above the desired temperature, whereas in the cupola the iron receives very little heat after it has been melted. Hence the possible temperature range of cast-iron melted in a cupola is smaller than that of non-ferrous metals melted in coke and gas furnaces. Many of the modern brass-melting furnaces, such as coke and oil tilters, are capable of bringing the metal to pouring temperature in less than an hour, and if it remain, say, another 20 minutes, subjected to full blast, the metal will be much too hot.

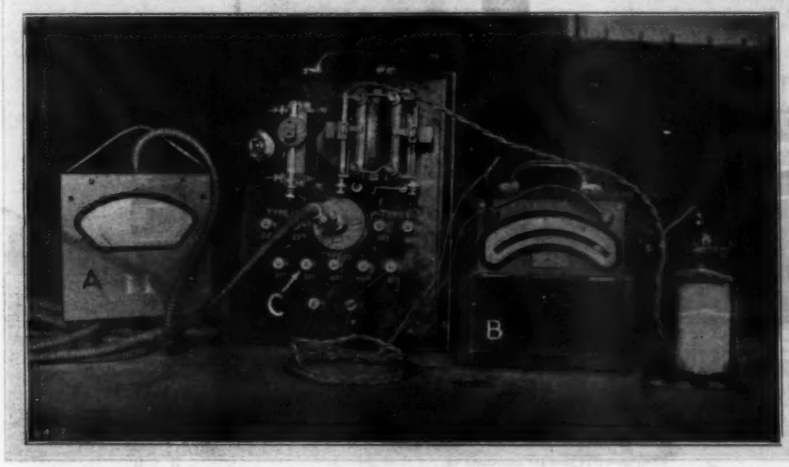
The measurement of temperatures of molten metals is a very difficult problem. It does not seem to have received the same attention as the measurement of temperatures of annealing furnaces. In such work as annealing, pyrometry has reached a high standard. Even small engineering shops have pyrometers installed in their furnaces, while the installations in some of the motor car works are on a most elaborate scale. In the foundry the position is very different. Comparatively few foundries have made any attempt whatever to measure temperatures, while the number of places where such readings are regularly taken is very small indeed. The instruments employed are :—

1. *Thermo-couples.*—The most commonly used couples have platinum as one element and an alloy of platinum and iridium or platinum and rhodium as the other. Owing to the high cost of platinum the wires are small in diameter, and also short. The general arrangement of such a pyrometer is a steel tube about 2 ft. long and 1 in. diameter, which serves as a handle. At one end this tube is screwed into a junction box in which the platinum wires are connected to the copper leads. At the other end the steel tube is fitted to a coupling piece. A graphite sheath, 13 in. long, 1 in. bore and ¼ in. thick, in walls, closed at one end, is screwed on to this coupling piece. Since graphite is permeable to gases it is necessary to encase the platinum wires in a silica tube closed at the lower end. The platinum wires are insulated throughout their length by short pieces of silica or porcelain tube. The whole arrangement is expensive, cumbersome and easily broken. The most serious objection, however, is the time lag. The thick graphite sheath and the inner silica tube both serve as all too efficient heat insulators, and readings are nearly always low. On this account much of the early data published on the effect of casting temperatures is unreliable. For example, tests on Admiralty gun-metal at temperatures below 1,000 deg. C. are quoted. Reference to the thermal diagram of the copper-tin alloys shows that part of the alloy is solid below 1,000 deg. C. In the writer's experience castings poured at even 1,030 deg. C. are nearly always unsound. A modification of this instrument is a nichrome sheath in place of graphite. The instrument is thereby rendered more robust, but, while the time lag is certainly less, it is still too great for ordinary use, and in addition the apparatus is heavy.

Protection tubes of carborundum and similar materials are now available. These are fairly strong, and have a low coefficient of expansion and a high heat conductivity. It is not permissible to have the platinum wires in direct contact with the carborundum tube, hence an inner tube of porcelain or pure silica is necessary.

Base metal couples are now made by several firms. In some of these an outer steel tube acts as one element, while the other element is a nickel or a nickel-copper alloy wire insulated by short pieces of porcelain tube. This construction is cheap, strong and allows of easy repairs, because when the hot junction is burned out it is only necessary to cut the tube and make a new weld. In some of the base metal couples the two elements are copper or nickel alloys, and hence require to be insulated both from each other and from the steel tube. One advantage of the base metal couple is that for a given temperature the E.M.F. is much greater than that given by a platinum couple. This allows a less delicate galvanometer to be employed, which is no small matter under foundry conditions. Base metal couples are quite satisfactory for taking temperatures of molten aluminium. For this purpose it is found that in order to get the best life the aluminium should never be allowed to come in contact with a clean surface of the couple. If the end of the couple which is immersed is previously painted with graphite or clay wash it will be found to last much longer; in fact, the writer has found the best life to be obtained from thermo-couples which have previously been used for some time in annealing furnaces and have thereby become covered with oxide.

2. *Resistance Pyrometers.*—These depend on the alteration of the resistance of a spiral of platinum wire at high temperatures. Great accuracy is possible by this method, and, in addition, by checking the resistance of the wire when cold, it is easy to detect any deterioration in the platinum. For application to molten metals, sheaths are necessary as for the thermo-couples, and a similar time lag is unavoidable.



A.—Instrument under Test. B.—Standard Millivolt Meter. C.—Terminals Connecting to the Resistances of Various Lengths of Rods.

Arrangement for Testing Pyrometers.

3. *Radiation Pyrometers.*—The radiation pyrometer has the advantage over the thermo-couple in that there is no contact between the molten metal and the instrument. The principle of the radiation pyrometer is, briefly, that the heat radiated from a hot body is, by means of a concave mirror, brought to focus upon a point which is the hot junction of a platinum thermo-couple. The thermo-couple is connected to a galvanometer in the ordinary way. The difficulty experienced with radiation instruments is that it is extremely difficult to obtain a surface of metal free from slag and oxide films. Unless this is done the readings are unreliable.

4. *Optical Pyrometers.*—The optical pyrometer has found considerable use in operations of annealing, re-heating, &c. While many of the cheaper instruments, in which the light radiated from a hot body is compared against a standard colour, are not to be relied upon to any great accuracy, instruments such as that made by the Cambridge Scientific Instrument Company, in which the light radiated from the hot body is compared with that from a standard lamp, can be considered reliable to a matter of well under 1 per cent. To obtain reliable readings from an optical pyrometer it is necessary that black body conditions be present. Since these do not apply to metal in a crucible, some correction is necessary.

Optical pyrometers are affected, if anything, to a greater degree than radiation instruments by the slag and fumes which are generally on the surface of molten brasses. In addition, optical instruments depend for accuracy on the human element, hence cannot be put into the hands of unskilled men.

To sum up the various instruments as far as foundry work is concerned; the thermo-couple and resistance pyrometer must be used with a sheath, and are hence too slow, while radiation and optical instruments give unsatisfactory readings on account of slag and fumes. To be really of service in the foundry a pyrometer should have the following characteristics: (1) It should be accurate within 1 per cent. (this means a maximum error of ± 10 deg. at 1,000 deg. C.); (2) it should be capable of use up to 1,300 deg. C. if need be; (3) it should be direct reading and involve no calculation or correction; (4) it should indicate the temperature of molten metal within at most 1 minute of immersion; (5) it should be strong and not easily put out of order; at any rate it should permit of easy and cheap repair; (6) it should not be too expensive.

I am strongly of the opinion that an immersion method is the only one of any use for molten metal, and further that the couple must be used either bare or with only a wash of refractory material on it.

Platinum is much too expensive. Iron and alloys of iron are too readily dissolved by the molten metals. The only commercial alloys left are those of nickel. For some time back a couple has been made in America of which one element is almost pure nickel and the other an alloy of nickel with about 9 per cent. of chromium. This gives an E.M.F. of over 40 millivolts at 1,000 deg. C., so that a robust galvanometer can be used with it. The two wires are encased for most of their length in a steel tube, leaving only a few inches of bare wire for immersion. Inside the tube they are insulated by asbestos woven to a tubular form, or by pieces of porcelain tube.

The writer has used this couple regularly for over a year, and has found it very satisfactory. At Cathcart the brass foundry insists on taking the temperatures of all melts of manganese brass and of all melts of gun-metal from which important castings are made. The wires are welded together, and when the junction is burnt through they can be rewelded in a couple of minutes in the oxy-acetylene flame.

In molten brass or manganese brass at 950 deg. to 1,000 deg. C. the couple lasts a very long time. In molten gun-metal the life of the junction depends on the temperature of the metal. At temperatures of 1,300 deg. C. and over the junction will only last one or two immersions, but at 1,150 deg. to 1,200 deg. C. perhaps six would be an average. The amount by which the couple is shortened each time the junction is burnt through is only 2 in. at most, so the actual cost of each immersion is very small.

The writer does not intend to dwell at length on the effect of casting temperatures since this paper is only concerned with the measurement of these. It might, however, be of interest to mention the results obtained on gun-metal of composition roughly: 88 per cent. copper, 9 per cent. tin, 2·5 per cent. zinc, 0·5 per cent. lead. The tests refer to greensand bars, 1 in. diameter, 8 in. long. When cast at 1,300 deg. C. the strength is approximately 9·5 tons per square inch, at 1,200 deg. C. 13 tons per square inch, reaching a maximum of over 16 tons at 1,150 deg. C. At temperatures of 1,050 deg. and under the bars are unsound. One might imagine that the range of temperatures within which gun-metal is cast in foundries would be comparatively small. The writer is quite convinced that in the average foundry the casting temperature varies from about 1,100 deg. C. up to 1,300 deg. C. At Cathcart it has been found that the casting range of manganese brass is very small, and that for the soundest castings the temperature should be 970 deg. C ± 20 deg. C.

It was stated at the outset that the measurement of temperatures of molten metal is very difficult. Although the couple spoken of is a distinct advance on those previously available there is much room for improvement. Brass founders can help in two ways. If a sufficiently strong demand for instruments is forthcoming the manufacturers will have an incentive towards research: also founders can help the makers of apparatus by giving facilities for test under service conditions. Owners of foundries can do much good by either giving the apparatus a thorough trial themselves or by allowing instrument makers to carry out tests in their works. The writer has found certain makers very willing to co-operate in this way, with the result that many small parts of the apparatus have been improved and much more satisfactory service obtained.

In conclusion, a word about the upkeep of pyrometers may be included. In works where a large number is kept their repair and calibration becomes an important matter. While some pyrometers work satisfactorily for long periods without attention, others most decidedly do not. If no indication whatever is given on the instrument the trouble may be due to: (1) Hot junction burnt through—this is evident at sight; (2) insulation of thermo-couple defective; (3) bad contact between thermo-couple and instrument. If the readings are incorrect they may be due to: (1) Alteration in resistance of couple—possibly caused by its length being reduced; (2) instrument out of balance; (3) alteration of tension in hair spring of instrument.

The writer might briefly describe an arrangement which Messrs. Kelvin, Bottomley and Baird made for him for testing galvanometers. The instrument used for checking is a sub-standard millivolt meter. The system is that the current from a battery, controlled by resistances, is sent through both the standard millivolt meter and the instrument to be tested. Any disagreement is at once noted. On this switchboard are placed resistances to suit all the various types of couple used, and also small resistances to compensate for the varying lengths of the couples. By this arrangement an instrument can be calibrated in a few minutes over its entire scale, making allowances for any length of couple.

The writer is indebted to the directors of Messrs. G. and J. Weir, Limited, for permission to read this paper.

* Paper read before annual meeting of Institution of British Foundrymen, at Glasgow, August 25, 1920.

The Telephone in Canada.—It is stated that the Saskatchewan Department of Telephones desires to equip the whole system with the automatic type of telephone and exchange.

THE P. AND O. LINER "NALDERA."

CONSTRUCTED BY MESSRS. CAIRD AND CO., LIMITED, GREENOCK, N.B.

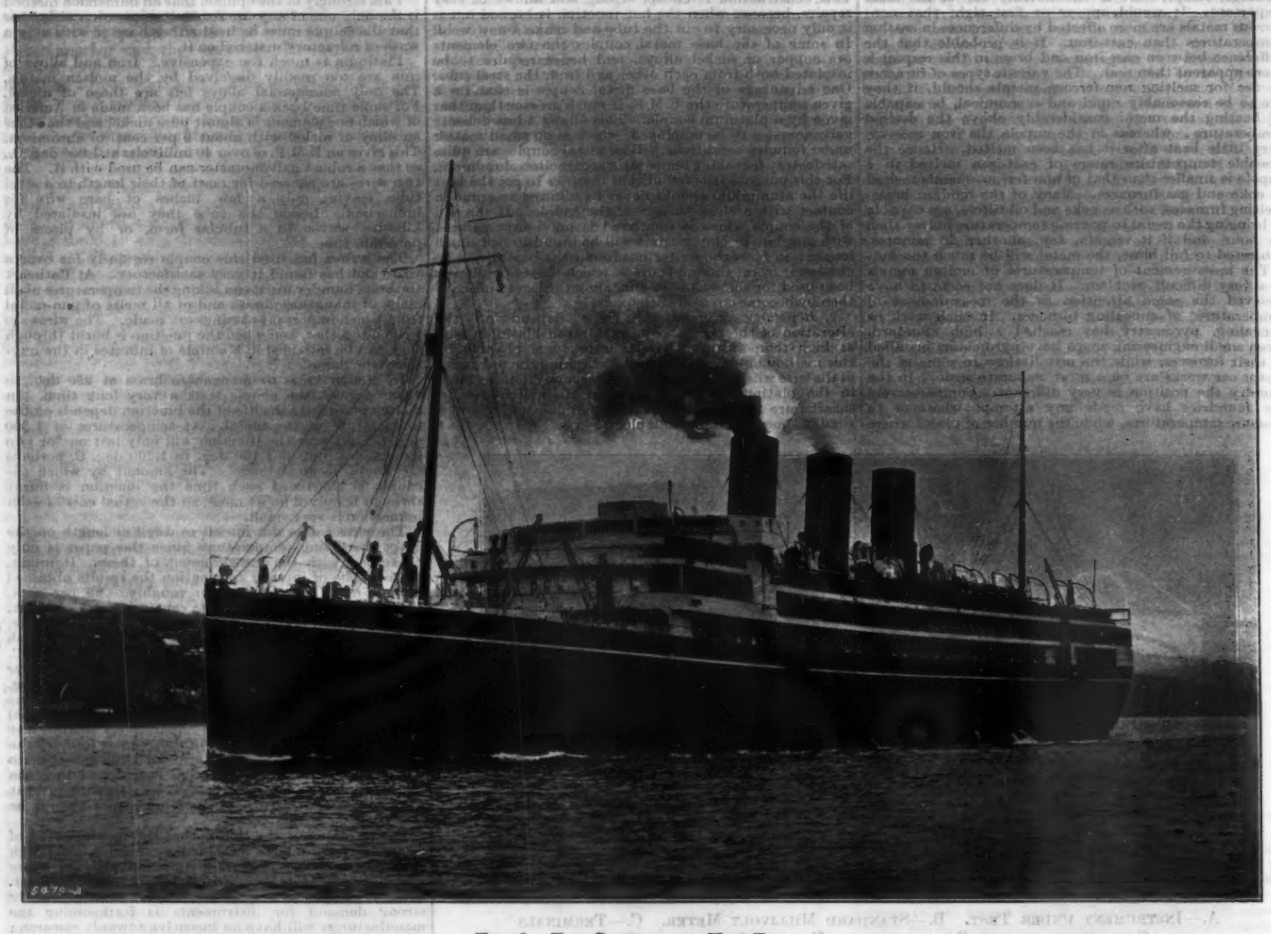


Fig. 1. The Steamer on Her Trial.

With the exception of the Narkunda, the Naldera, which was built by Messrs. Caird and Co., Limited, of Greenock, for the passenger and mail service to India and Australia of the Peninsular and Oriental Steam Navigation Company, is the largest unit in the fleet of that company, and it is in any case the largest ship so far constructed on the lower reaches of the Clyde. The order for the Naldera was placed early in 1914, and the keel was laid at that time, but before the construction had proceeded very far it was suspended on account of the war. Two years elapsed before the work was recommenced so that the launch did not take place until the end of December, 1917. The vessel was first completed as a cargo carrier in 1918, and afterwards fitted out as a troopship and armed cruiser, but was never used for either of these services, and finally, after the conclusion of the Armistice, the ship was restored to the Peninsular and Oriental Steam Navigation Company for completion along the lines originally intended.

The designs for the ship were prepared by Messrs. Caird and approved by Mr. C. G. Deane, the owners' naval architect, who also supervised the construction. The general view of the vessel, Fig. 1 on this page, which is reproduced from an excellent photograph by Messrs. Maclure, Macdonald and Co., of Glasgow, illustrates two features of the design which differentiate the Naldera from other P. and O. vessels, viz., the cruiser stern and the third funnel; the aftermost funnel is, however, chiefly used for ventilation purposes. Other illustrations of the design, which will be referred to later, can best be followed by an examination of the elevation and deck plans, Figs. 2 to 10, reproduced on Plate XXVI, which accompanies this issue; some particulars of the scantlings are also given in the half midship section of the ship, Fig. 11, on the opposite page.

The overall length of the Naldera is 605 ft., while the length between perpendiculars is 581 ft. The moulded breadth is 67 ft., the moulded depth to the upper deck 40 ft. 9 in., and the height from the keel to the navigating bridge, 77 ft. The vessel has a gross tonnage of 15,825 and draws 29 ft. 6¼ in. of water when fully loaded. Accommodation is provided for 426 first-class passengers and 247 second-class passengers, while the officers and crew together number 462. General cargo is also carried in holds having a total capacity of 253,320 cub. ft., and insulated holds having a volume of 103,360 cub. ft., are also provided for conveying perishable goods in cold storage. The bunker capacity of the ship is 2,940 tons.

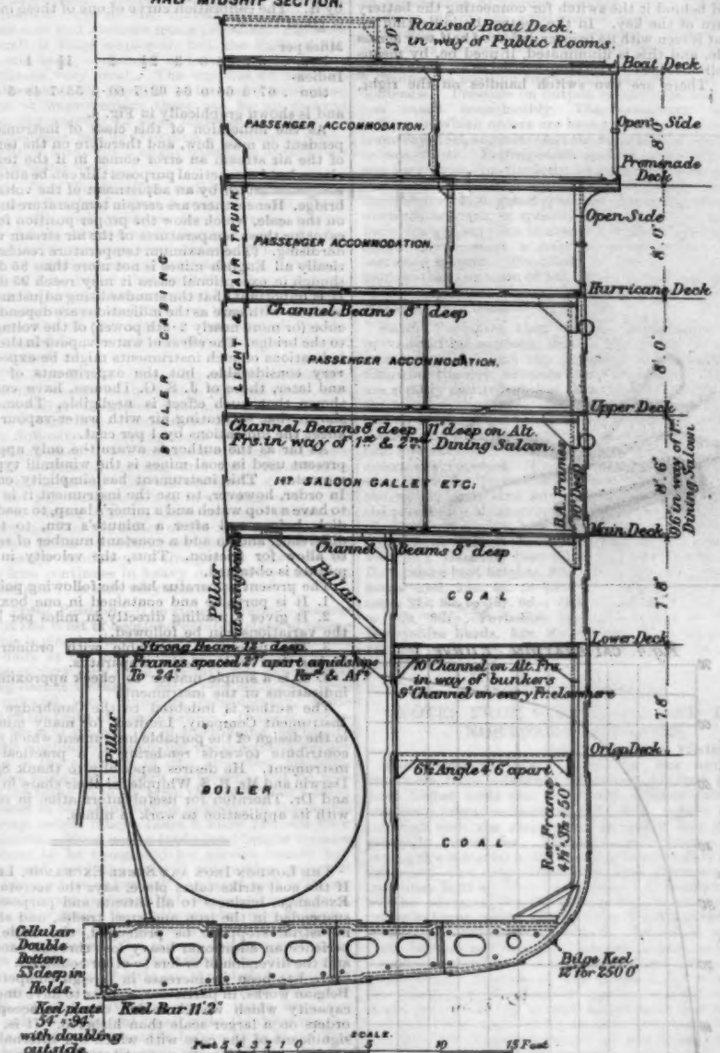
The hull is subdivided by 11 transverse watertight bulkheads, 10 of which extend to the upper deck, while the fore-peak bulkhead is carried up to the hurricane deck. Further protection is provided by the cellular double bottom which extends over the whole length and breadth of the ship, and has a depth of 4 ft. 9 in. on the line of the keel. These arrangements can easily be followed from the elevation and deck plans on Plate XXVI, and it will also be noticed from Fig. 7 that there are three fireproof bulkheads in the upper 'tween decks. These, with the fore-peak bulkhead, divide this space into five parts, each of which can be isolated in case of fire. Five of the decks, viz., the orlop, lower, main, upper and hurricane decks, extend for the whole length of the ship, while above these are the promenade and boat decks, each of which has a length of 440 ft., and projects for a distance of 2 ft. 6 in. beyond the moulded breadth of the ship as shown in the midship section, Fig. 11, on the opposite page. These two decks are divided between the forward and amidships funnels, and are connected by expansion joints.

Above the boat deck is the navigating bridge, shown in plan in Fig. 4 on Plate XXVI. On it is situated the captain's cabin and the wheel house, which is exceptionally well equipped with navigating appliances. In addition to the usual engine room and docking telegraphs, communication is provided with the engine room, forecastle, and docking stations by means of loud speaking telephones. Engine direction indicators and revolution counters are also fitted on the bridge as well as compasses and signalling appliances of the latest type. Wireless apparatus is also carried, the operating station for which is situated on the boat deck immediately forward of the first funnel. The officers are accommodated in cabins on the boat deck under the navigating bridge, and a wide promenade is reserved for their sole use at the forward end of the deck. The engineers are also housed on the boat deck in cabins surrounding the engine casing at the after end and a portion of the deck is also reserved for their use. This new feature in engineers' accommodation is much appreciated by the engineering *personnel*. Twenty-three lifeboats and a motor launch are stowed on the boat deck as shown in the plan, Fig. 3 on Plate XXVI. The boats, which are hoisted by means of hydraulically operated bollards, are of sufficient capacity to accommodate the whole of the passengers and crew.

The Naldera will maintain the Peninsular and Oriental Company's reputation in the matter of passenger accommodation, some of the principal features of which are illustrated in Figs. 12 to 15 on page 282. As shown in the plan of the promenade deck, Fig. 5 on Plate XXVI, the midship portion of this deck is reserved for first-class passengers and the principal public rooms, viz., the lounge, divan, smoking room and music room are also situated on this deck. Of these apartments the three last-mentioned are illustrated respectively in Figs. 12, 13 and 14 on page 282. As will be seen from Fig. 14, the music room is a spacious and comfortable apartment with bays along each side. It is lighted from the front and sides by large windows and from the roof by a skylight over the well. This well, which

occupies the centre of the saloon and is surrounded, as shown, by a balcony rail, forms the principal feature in the scheme of decoration. It extends down through three decks to the dining saloon on the main deck, and terminates at its upper end in an ornamental glass dome on the boat deck. The walls of the music room are panelled in dark oak ornamented with rich mouldings and carvings, while the ceiling is of plaster in old ivory colour. The same colour also forms the ground inside the well and on the inner surface of the well below the level of the music room is a fine frieze painted by Professor Moira. The whole effect is very impressive and pleasing. The companion divan and lounge, which are illustrated in Fig. 12 on page 282, adjoin the music room, and have a similar colour

HALF MIDSHIP SECTION.



and decoration scheme. Between the forward and intermediate funnels is a well-equipped gymnasium located in a special deck-house. Further aft are situated a number of single berth staterooms and the first-class smoking room and verandah. The appearance of the smoking room is well shown in Fig. 13, and it should be mentioned that this apartment, as well as the other public rooms situated on the promenade deck, are all 11 ft. high. Over the smoking room is a well 15 ft. high, as can be seen in our illustration, and this well, which is covered by an ornamental glass skylight, gives the room a more spacious appearance and also facilitates ventilation. Outside the smoking room is a large verandah communicating with another on the boat deck above by means of a special stairway.

The hurricane deck, a plan of which is given in Fig. 6 on Plate XXVI, is the weather and working deck of the ship. Forward are the steam windlass and two warping capstans, both steam driven. Two similar capstans are fitted aft. Abaft of the windlass double breakwaters are provided to protect the open deck and the passenger accommodation from heavy seas. Four hydraulic cranes, which are visible in the general view of the ship on the opposite page, are also fitted on this deck for handling goods to and from the forward holds, and two similar cranes are provided for use in connection with the after holds. Three more hydraulic cranes are mounted on the boat deck, as shown in Fig. 3, Plate XXVI, two being used for the forward holds and one for the after holds. Power for these cranes and for the bollards used, as previously mentioned, for hoisting the lifeboats, is supplied by a hydraulic pumping engine and accumulator situated in the main engine room. A deckhouse amidships on the hurricane deck having a total length of 300 ft. is entirely occupied by first-class passenger accommodation consisting mainly of double-berth cabins, although there are a few single-berth cabins in the forward part. On each side of this deckhouse and extending along the whole of its length is a clear promenade for passengers. Further aft is a separate deckhouse, in which the second-class music room and smoking room are situated, and right aft are the laundry, and washhouses and shelters for the native crew.

The upper deck is almost entirely devoted to first-class passenger accommodation provided, for the most part, in two-berth and three-berth cabins. There are, however, four special cabins each provided with a separate bath-room and lavatory. Second-class passengers have some accommodation on this deck further aft and at the extreme after end the native crew have their quarters. A watertight trunk giving access to the tunnel enables the natives to reach the stokeholds without passing among the passengers. Both first-class and second-class dining saloons are situated on the main deck. Of the former, we reproduce a photograph in Fig. 15 on page 282; it has seating accommodation for 384 persons. The saloon is 9 ft. 6 in. high from deck to ceiling, and the dome over the well, referred to previously, is 42 ft. above the deck. The walls and ceiling are in old ivory colour and this colour also forms the ground of the decorations inside the well. A row of electric lamps is placed on a ledge half way up the well, with reflectors arranged to illuminate the pictures in the frieze; electric fans are fitted over the tables to keep the air in circulation. Two electric lifts are provided for service between the dining saloon and the music room, with landings at the intermediate decks. At the after end of the saloon a handing room extends across the whole width of the ship and abaft of this are the pantry, saloon bar, galley, bakery and accessory offices, the whole forming a convenient and expeditious arrangement for preparing and serving the food. Most of the second-class passengers are berthed on the main deck, the arrangement of the accommodation being clearly shown in the deck plan, Fig. 8, on Plate XXVI. As will be seen from the figure, the second-class dining saloon, which seats 250 persons, occupies the centre part of the space allotted to second-class passengers. In both first and second-class accommodation a fresh water supply is led to each stateroom from a tank on the boat deck, and a waste pipe is connected to the drainage system of the ship from each lavatory basin. The spaces on the lower or orlop decks, plans of which are given in Figs. 9 and 10 on Plate XXVI, are used for cargo, stores, baggage and mails; the capacity of the insulated stores on the orlop deck is 15,670 cub. ft. There are four cargo holds forward and two aft. No. 2 hold being insulated up to the lower deck level and No. 3 up to the main deck level; No. 4 hold and the 'tween decks space can be used as a reserve bunker if required. Fresh water for the passengers is carried in the fore and after peaks and also between the shaft tunnels, while a supply of fresh water for laundry purposes and reserve feed for the boilers is carried in the double bottom. The total capacity of the fresh water tanks is 886 tons, and of the ballast tanks, 1,890 tons.

(To be continued.)

A PORTABLE DIRECT-READING ANEMOMETER FOR THE MEASUREMENT OF VENTILATION OF COAL MINES.*

By Professor J. T. MACGREGOR-MORRIS, M.I.E.E.

At the Dundee meeting of the British Association in 1912 the author read a paper entitled "The Electrical Measurement of Wind Velocity," and showed certain experiments illustrating the application of the principles involved. Subsequently, in order to obtain correct measurements of the velocity of air at various atmospheric temperatures it became necessary to introduce a modification of the method first described.

The principle which is utilised in the apparatus which is the subject of this paper may best be illustrated in the following manner:—When a length of thin wire in air is heated by the passage of an electric current of constant strength, the wire attains a steady temperature in a second or two. Heat is then being taken away from the wire by the motion of the air passing it, at the same rate as that at which it is receiving heat from the electric

current, and the rise in temperature will be the smaller the higher the velocity of the air. This fact can be utilised to determine the rate at which the air is passing. Generally speaking, when a wire changes in temperature its length changes, as does also its electrical resistance. Either of these two effects can be used. In many ways the change of length would be simpler to use, but owing to the minuteness of the change of length it is probably better to use the change in electrical resistance. To obtain the same magnitude of effect mechanically a wire would require to double in length when raised to a temperature of 400 deg F. or 500 deg. F. However, as the principle of the instrument about to be described may be more easily grasped by some mechanically, the above crude mechanical model (*Fig.* 1) is put forward.

Four thin wires *a*, *b*, *c* and *d* each of the same length are arranged as shown, and a constant electric current is maintained flowing through the two paths in parallel *ab* and *cd* entering at X and leaving at Y, *b* and *c* are enclosed in, but not touching, two thin walled metal tubes which shield these two wires from the cooling effect of the moving air. The other two wires *a* and *d* are fully exposed to the air. If the material of the wires is such (say, for example, iron) that an appreciable change of length takes place with change of temperature, then the greater the velocity of the wind blowing upon

* Paper read before Section G of the Cardiff meeting of the British Association, August, 1920.

the apparatus, the shorter the wires *a* and *d* will become, whilst wires *b* and *c* remain practically unaltered in temperature and consequently in length also. A pointer, made of insulating material, connecting the junction of *a* and *b* with the junction of *c* and *d* will move over to the right as the velocity of the wind increases.

Such apparatus as this of necessity gives, for low velocities, a more open scale than for higher velocities. Consider, for instance, the case of a wire for which the temperature elevation above the atmospheric temperature is reduced to half by a wind velocity of three miles per hour, then any further increase of velocity, no matter how great, can do no more than reduce the temperature down to that of the atmosphere. Such an instrument would therefore have the three miles per hour mark half-way across the scale, whilst a hundred miles per hour or more would only double the reading. This shows that the apparatus in this form is mainly suited to the measurement of low velocities, say, up to 10 miles per hour or perhaps 20 miles per hour.

We now turn from the method of using the change of length with temperature, to that of utilising the change of resistance with temperature, and then the only alteration which we have to make is that of replacing the insulating pointer connecting the junction of *a* and *b* to that of

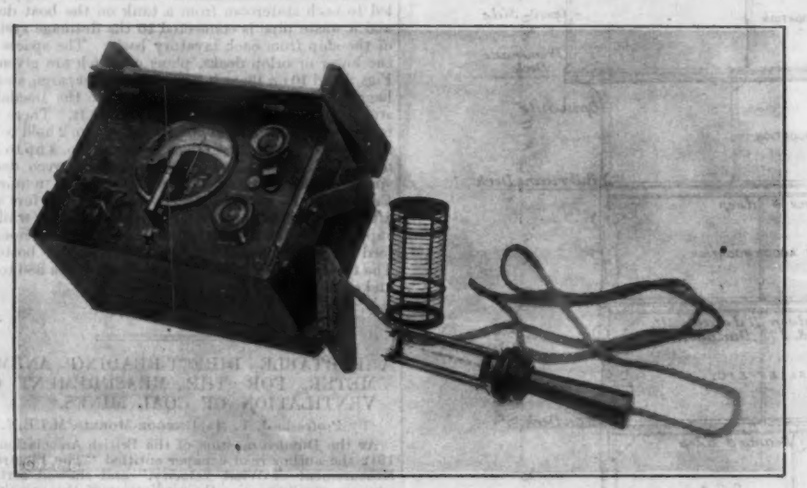
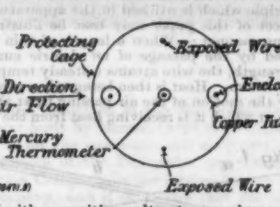


Fig. 2.

Fig. 3. SECTION THROUGH ANEMOMETER HEAD



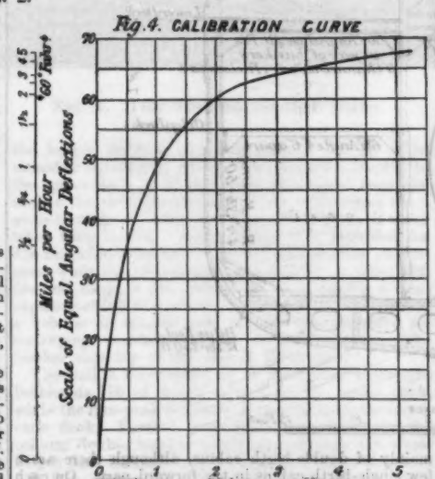
c and *d* with a sensitive voltmeter or galvanometer. This arrangement then constitutes the well-known Wheatstone Bridge. In both the mechanical and the electrical model it is obviously essential that the current through (or the voltage applied to) the bridge be maintained constant, as variations in these quantities seriously affect the indications of the pointer in the mechanical model, and the voltmeter in the electrical arrangement.

It will be clear that apparatus operating on the above lines has many fields of action, and many investigators have worked at the subject of the electrical measurement of wind velocity. This is not the occasion to attempt to outline their work, but one cannot pass over in silence Kennelly's pioneer experimental work,* L. V. King's classical Royal Society paper of 1914,† and more recently, J. S. G. Thomas's excellent work published before the Physical Society of London and elsewhere.‡

In the present paper it is proposed to confine attention to the development of a practical form of portable anemometer for use in coal mines. A consideration of the materials available suggests the use of platinum, nickel or tungsten. Platinum, though in many respects suitable, is hardly robust enough to stand the kind of treatment it is likely to receive. Nickel is good if extreme care is taken in its selection. Similarly, excellent results have been obtained with tungsten. There are many points which call for considerable experience, in the choice and the handling of these wires, in the soldering and the adjustment of tension, and in other matters, including the eliminating of errors due to thermo-electricity. In the apparatus about to be described a very special nickel wire has been used having an electrical resistivity temperature coefficient of 0·474 per cent. per deg. C. reckoned on 20 deg. C.

The whole apparatus is entirely contained in a box measuring 10 in. by 6¼ in. by 7 in. deep and weighs 13¼ lb. complete. It is illustrated in the accompanying figure (Fig. 2). The pair of exposed sensitive heated wires, the enclosing tubes for the other pair of wires, and the thermometer which together form the anemometer head (shown diagrammatically in Section in Fig. 3) are carried by the ebonite handle, and are shown on the right in front. The protecting cage (which has been removed only for the purpose of showing the details) will be seen at the back. The recess in the box underneath the indicating instrument holds the anemometer head and the connecting length of flexible when the instrument is not in use. The two-volt accumulator will be seen on the left, and behind it the switch for connecting the battery by a turn of the key. In the centre the indicating instrument is seen with its pointer deflected half-way across the scale, and this is illuminated, if need be, by means of a small shielded electric lamp carried in an overhanging holder. There are two switch handles on the right,

Fig. 4. CALIBRATION CURVE



the one in front being a rheostat handle for adjusting the voltage applied to the bridge to the correct value for the particular air temperature, this adjustment being made when using the indicating instrument as a sensitive voltmeter, the switch handle at the back being placed on the right-hand stud marked "standardise." After this adjustment, which takes only a few seconds, has been made, the switch handle is thrown over to the left-hand stud marked "anemometer" when the pointer of the measuring instrument swings to a reading giving the velocity of the air passing the anemometer head in miles per hour. There is a simple but effective device which only allows of the box being closed if the needle of the indicator has been clamped, and, should the battery by accident be left on, it is automatically switched off by the action of closing the box.

To obtain the best results, the anemometer head should be held at arm's length with one of the two little brass screws at the top of the ebonite handle facing in the direction of the wind, and the checking of the standardisation at the right temperature should naturally be looked to at intervals. If one is in doubt as to the correctness of the instrument, it is a simple matter to check the reading approximately, by walking round a table on which is placed the anemometer box, carrying the anemometer head in one's hand at a known radius (using the flexible for this purpose) and taking the time of one complete turn round the table, and so getting a measure of the velocity. Naturally a certain allowance has to be made for the "swirl" created in the air by the person moving through it.

As the instrument has such an open scale near its zero, it is very exceptional to find it indicating zero velocity, as it easily gives an indication for a velocity of one-twentieth of a mile per hour, and probably even a fifth of this would give a measurable indication. In its present form, however, its best range is from ½ mile per hour up to, say, 5 miles per hour. Movements of air, which it is quite impossible for us to feel are indicated by it. The calibration curve of one of these instruments is given below.

Miles per hour	5·0	4·0	3	2½	2	1½	1	¾	½
Indication	67·5	66·0	64	62·7	60·5	55·7	48·5	43·0	35·5

and is shown graphically in Fig. 4.

As the indication of this class of instrument is dependent on mass flow, and therefore on the temperature of the air stream an error comes in if the temperature alters, but for practical purposes this can be automatically compensated for by an adjustment of the voltage on the bridge. Hence, there are certain temperature index marks on the scale, which show the proper position for the indicator for these temperatures of the air stream when standardising. (The maximum temperature reached in practically all English mines is not more than 85 deg. Fahr., though in exceptional cases it may reach 95 deg. Fahr.) It is important that the standardising adjustment should be done with care as the indications are dependent on the cube (or more nearly 2·8th power) of the voltage applied to the bridge. The effect of water-vapour in the air on the indications of such instruments might be expected to be very considerable, but the experiments of Kennelly, and later, those of J. S. G. Thomas, have conclusively shown that such effect is negligible, Thomas having shown that saturating air with water-vapour does not affect the indications by 1 per cent.

As far as the author is aware the only apparatus at present used in coal mines is the windmill type of anemometer. This instrument has simplicity on its side. In order, however, to use the instrument it is necessary to have a stop watch and a miner's lamp, to read the little dials before and after a minute's run, to take their difference, and to add a constant number of revolutions to allow for friction. Thus, the velocity in feet per minute is obtained.

The present apparatus has the following points:—

1. It is portable and contained in one box.
2. It gives a reading directly in miles per hour, and the variations can be followed.
3. The precision attainable with ordinary use is higher than with existing apparatus.
4. It is a simple matter to check approximately the indications of the instrument.

The author is indebted to the Cambridge and Paul Instrument Company, Limited, for many minor points in the design of the portable instrument which materially contribute towards rendering it a practical portable instrument. He desires especially to thank Sir Horace Darwin and Mr. R. S. Whipple for their share in the work, and Dr. Thornton for useful information in connection with its application to work in mines.

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* A. E. Kennelly, Wright and Van Bylevelt, Trans. Amer. I.E.E., vol. xxvi, page 969, 1907, also vol. xxviii, pages 363–396, 1909.

† L. V. King, Convection of Heat from Small Cylinders, Phil. Trans. Roy. Soc., Series A, vol. ccxiv, pages 373–432.

‡ J. S. G. Thomas, The Hot-Wire Anemometer, Phil. Mag., vol. xxxix, May, 1920.

The London Iron and Steel Exchange, Limited.—If the coal strike takes place, says the secretary of the Exchange, business to all intents and purposes will be suspended in the iron and steel trades, and should the industrial stoppage be prolonged, the trade will experience an additional heavy loss through cancellations and the diversion of orders to other countries. Recently there has been an increase in foreign competition and Belgian works, in particular, appear to have unemployed capacity which would enable them to accept export orders on a larger scale than hitherto. It is, perhaps, significant of the care with which our internal troubles are followed by foreign competitors that their quotations have become noticeably firmer during the past few days, possibly at the prospect of reaping a harvest if British industry is paralysed from lack of coal.

"Safety First."—At the Machine Tool Trades Exhibition to be held at Olympia in September, a convention will be held under the joint auspices of the Home Office and the British Industrial "Safety First" Association. There will be two sessions, at which papers will be discussed. Engagements permitting, the Home Secretary will preside at the morning session and Lord Leverhulme in the afternoon. Invitations to the convention are being extended to the managements and workers of the principal industries throughout the country, to employers' federations, employees' organisations, Whitley Councils, the Federation of British Industries, and the National Union of Manufacturers; also to representatives of Government Departments and numerous other personalities prominent in commercial and industrial circles. The arrangements for the conference are in the hands of Mr. Gerald Bellhouse, C.B.E., the Deputy-Chief Inspector of Factories and Workshops, and Mr. H. E. Blain, C.B.E., the well-known operating manager of the Underground Railway and London General Omnibus Group.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—There has been a steady demand for ship plates during the past week, and although a number of new vessels were cancelled recently there are sufficient orders on hand to use up the total output of plates for many months. All the mills are running full and deliveries are barely equal to requirements. Structural sections are not quite as active as they were, but a very good business is passing. Makers of black sheets continue to be exceptionally busy and there is no falling-off in the demand. The amount of work booked totals to a very large tonnage, and it will take a considerable time to clear it off, and few new orders can be accepted for near date delivery until present bookings are reduced. For galvanised sheets the outlook is very good, and quite recently some very satisfactory lines have been negotiated. India and Australia, as well as South America, are in the market for galvanised articles just now and business seems probable. The steel trade overall is fully employed, but the bulk of the output is still being consumed at home and the export trade continues very small. The supplies of hematite have not been any too plentiful of late, and until these show signs of improvement there can be no marked increase in the amount of steel material available for home requirements, and no extension of the foreign trade. Prices continue firm, but a slight change is anticipated during the ensuing week.

Malleable Iron Trade.—The malleable iron makers in the West of Scotland report a continuance of steady conditions and much pressure for deliveries against contract. All the works are fully employed, but supplies of raw material are not over satisfactory, and the prospects in that direction are not reassuring. Forward inquiries could be better, but until the labour position throughout the country has improved buyers are holding off. Prices are strong and have an upward tendency, but the amount of the advance necessitated by the increases caused by the new railway rates has not yet been determined.

Scotch Pig-Iron Trade.—The great scarcity of foundry iron is still the feature in the Scotch pig-iron trade, and indeed nearly all grades of iron are scarce and the market continues to rule firm. Consumers keep complaining about the difficulty in getting large enough deliveries for their requirements, but makers are doing their best to keep all customers moving, and their distribution scheme is still in force. The various works are running steadily, but the tonnage is not increasing, and so all consumers are being kept on short rations. Prices are without change, but the effect of the new railway rates is at present under consideration, and alongside them goes the easier tendency of freight on inward ore. Hematite iron continues in heavy demand by the local steelmakers and it is still very scarce.

General Trade Position.—The state of trade in general throughout the West of Scotland exhibits signs of easing off, and this is clearly shown by the number of workmen who call daily at the gate-houses seeking employment, as it is not so very long since difficulty was experienced in securing decent workers. Some establishments have already reduced their numbers considerably, while others are on the point of doing likewise. In the engineering shops there is quite a lot of work doing, especially in the sugar machinery branch, but the greatest difficulty at present is the shortage of iron and steel material. Shipbuilders have lots of work at present, but no new contracts are being fixed up, with the result that a slack time is ahead of the shipbuilding industry in the course of next year, unless labour takes a more rational view of the situation. Even with a fairly good freight the new vessels about to be completed for service cannot pay their way, and until the cost of production eases off considerably few new orders will be placed with builders. Labour troubles are again on the forefront of the horizon, and within a few weeks the whole country may be in the throes of one of the fiercest labour battles experienced for quite a long time. The miners are now voting for or against a strike, and if the affirmative is accepted it will not take long to bottle up the whole industry of the country. That this incessant demand for more wages all round is driving away all trade from our shores is only too apparent to all right-thinking people, and a firm stand must be made before all is lost. The Cabinet has a chance to gain the confidence of the country now in the approaching coal crisis, and it is to be hoped that a firm attitude will be taken up. Meanwhile we can only wait and see.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

More Labour Trouble.—Unless a settlement is reached before Saturday next, the engineering trades are likely to be involved in further serious labour trouble. Arising from the employment of a non-union foreman at Messrs. Cammell Laird's Penistone works, the Electrical Trades Union have forced a national issue. Negotiations have reached a deadlock, and at the moment a lock-out of electricians is threatened. Local officials of the union state that the conflict, if it materialises, will be confined to firms who are members of the Engineering Employers' Federation. The suspension of "key" men in this industry would aim a serious blow at production generally, but the employers in Sheffield stand firmly by their right to nominate whom they choose as departmental foremen, and are not prepared to capitulate without a stern struggle.

Iron and Steel.—More men have been discharged from the heavy engineering section, but still the gross amount of unemployment is not such that gives rise to serious anxiety. While the delicacy of the current trade position is responsible for a good deal of speculation as to the future, a growing feeling prevails that normal conditions can quickly be restored by mutual concessions from employers and employed. The number of inquiries in circulation for steel, machinery, and tools for Continental reconstruction and for renewals in the Colonies and other overseas markets, makes it evident that only the restoration of those conditions which would enable manufacturers to give firm price quotations is necessary to attract a fresh influx of orders. Foreign buyers of engineering products appear to have much to offer in the way of new business, but for the most part seem to be awaiting the advent of more favourable circumstances, both as to price and delivery, before committing themselves to heavy purchases. Meanwhile a number of departments are managing with difficulty to maintain an appearance of normal activity. The crucible steel trade is hit by the existence of heavy surplus stocks remaining from Government disposals. Makers of high-speed steel are badly hampered by the dearth of vanadium though the slump in prices of other alloys puts them in a favourable position respecting the covering of forward contracts. Pressure on output at the large rolling mills has ceased considerably. The somewhat niggardly fashion in which orders are being placed for railway and tramway steel, suggests that the largest renewals have yet to be covered. Rolling-stock makers, on the other hand, are very busy, particularly as regards locomotive construction. Virtually all classes of tools, with the exception of high-speed qualities, are going away under contract account as quickly as they can be produced. Deficiency in supplies of raw and semi-finished materials continues to exert a restricting influence on manufacturing output. Premiums of 10*s.* to 15*s.* are being paid on the minimum of 14*l.* 7*s.* 6*d.* for prompt deliveries of foundry iron. Increased tonnages of bars, hoops and sheets are needed.

South Yorkshire Coal Trade.—Exceptional activity prevails in all sections, due to the threat of extensive labour trouble, and the prospect of increased prices following the new advance in railway rates. Shipments are strictly controlled, but there is keen competition for the tonnage available. Gas fuels for despatch to France realise upwards of 11*l.* per ton. Manufacturers of all classes, and railway companies, are pressing collieries for full contract deliveries for the purpose of enlarging emergency reserves. Under this influence, slacks have strengthened. Householders are taking advantage of the widely circulated advice to fill their cellars against the possibility of interrupted deliveries. All descriptions of cokes are readily being absorbed at maximum rates. Quotations:—Best branch hand-picked, 37*s.* 2*d.* to 38*s.* 2*d.*; Barnsley best Silkstone, 37*s.* 2*d.* to 37*s.* 8*d.*; Derbyshire best brights, 35*s.* 2*d.* to 36*s.* 2*d.*; Derbyshire house coal, 32*s.* 8*d.* to 33*s.* 2*d.*; Derbyshire best large nuts, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire small nuts, 31*s.* 8*d.* to 32*s.* 8*d.*; Yorkshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; rough slacks, 28*s.* 2*d.* to 29*s.* 2*d.*; nutty, 27*s.* 2*d.* to 28*s.* 2*d.*; smalls, 23*s.* 2*d.* to 24*s.* 2*d.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—As was anticipated, producers have advanced Cleveland pig-iron prices to meet higher costs due to heavier railway rates which become operative next month, but buyers are well satisfied with the rise, which is rather less than was generally looked for. The extra rail charges for conveying raw material to the furnaces has certainly rendered necessary the step taken by the ironmasters, who announce that as from September 1 Cleveland pig-iron will be advanced by 7*s.* 6*d.* per ton, thus making the prices to home consumers 225*s.* for No. 3 and the inferior grades, and 237*s.* 6*d.* for No. 1. Producers adhere to their decision not to sell for abroad so long as supply is insufficient for home needs, and there are no export quotations. Customers are pressing for supplies of Cleveland iron, Scotland in particular clamouring for larger deliveries, but though distribution has expanded somewhat this week owing to more iron being available through last week's holidays at the local consuming works, supply is still inadequate.

Hematite Iron.—Little news is ascertainable concerning hematite. Prices have not been raised, it being considered that cheaper foreign ore enables this branch to bear the burden of increased railway freights. Makers having sold their output to the end of the year are not in the market, but merchants are still offering parcels. Nos. 1, 2 and 3 East Coast brands are 260*s.* and No. 1 is 262*s.* 6*d.*; whilst for shipment to France, Belgium and Italy, mixed Nos. are 265*s.* and No. 1 is 267*s.* 6*d.*

Foreign Ore.—Sellers of imported ore are keen to secure contracts, and consumers are less disinclined to listen to offers so that renewal of activity is looked for. Orders might be placed at equal to 47*s.* to 48*s.* ex-ship Tees for best rubio.

Coke.—Coke keeps strong. Supply is by no means plentiful, but essential needs of local consumers are receiving adequate attention, and there is still a little to spare for export. The unsettled state of the coal trade however has checked forward business. For home purposes medium blast-furnace coke is 62*s.* 9*d.* at the ovens, and quality low in phosphorus is 65*s.* 3*d.* at the ovens. For export, furnace and foundry coke are quoted 250*s.*, and gas-house product is 245*s.*

Manufactured Iron and Steel.—Finished iron and steel manufacturers have a great deal of work on hand, and they report continued fairly good home inquiries, but foreign trade is stagnant. Growing competition of Belgium, and of America, is certainly causing some uneasiness, but at the same time traders express faith in return of demand from abroad, arguing that as the world requirements for iron and steel are still vast, this market is likely to receive its share of foreign orders. Values of most material are upheld. Common iron bars are 30*l.*; marked bars, 32*l.*; iron angles, 30*l.* 15*s.*; rivets, 38*l.*; channels and flats, 23*l.* 5*s.*; rounds and squares, 25*l.* 10*s.*; steel ship, bridge and tank plates, 23*l.* 10*s.*; steel angles, 23*l.*; steel boiler plates, 30*l.*; steel joists, 23*l.*; soft steel billets, 25*l.* 10*s.*; hard steel billets, 26*l.* 10*s.*; heavy sections of steel rails, 25*l.*; fish-plates, 30*l.*; corrugated galvanised sheets, 46*l.*; and black sheets, 40*l.*

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—The uncertain outlook in respect to the labour position and the threat of the national coal strike has brought new business to almost a standstill, as operators generally show a disinclination to negotiate for delivery in the coming month pending further developments. Dealings for early delivery too are considerably curtailed and difficult to arrange because of the scarcity of supplies and the stringency of the Coal Mines Department in respect to export releases. Except for British coal depots abroad releases of large descriptions have been suspended for the past week and exporters have been informed that there is practically no hope of a change in the position until the end of the month at least. Throughs and smalls are practically unobtainable on the market as colliery outputs are inadequate to meet requirements and in the majority of cases absorbed in the fulfilment of contract obligations. Bunkers are exceedingly scarce, and there are instances of loaded vessels being delayed a week and more because of the inability of owners to obtain their bunker requirements. There are also a considerable number of vessels unable to leave the district in ballast because of the scarcity of bunkers. Though colliery owners by a voluntary arrangement supply bunkers at fixed prices of 80*s.* for large, 75*s.* for throughs and 60*s.* for smalls, middlemen holding supplies demand, and are obtaining, a premium of from 5*s.* to 10*s.* per ton, while at Swansea as much as 105*s.* has been paid for Swansea throughs, or 30*s.* over the colliery fixed price, and 90*s.* for steam large. It has now been decided to allocate to individual makers the quantity of coke which they are permitted to export and permits, as for coal, have been issued for the purpose. The quantity available for foreign shipment is about 10 per cent. of the total make, and as this is nothing like sufficient to meet requirements prices are firm with 220*s.* to 225*s.* readily obtainable. The shortage of small coal has retarded the make of patent fuel and as manufacturers generally are fully booked up with contract commitments buyers on the open market are compelled to pay anything from 135*s.* to 140*s.*, and at these figures are glad to get supplies. Pitwood is irregular owing to an accumulation of imports after the recent dischargers' strike. Though there is a fair demand the trouble is that buyers are unable to take delivery because of a shortage of wagons. Prices range from 50*s.* to 55*s.*, but these figures could be discounted by 2*s.* 6*d.* to buyers able to take immediate delivery.

PERSONAL.—Messrs. Murray Coombs and Richards, who have been appointed representatives for the United Kingdom and Europe, by Messrs. W. G. Watson and Co., Limited, Sydney, Australia, have moved to Premier House, 150, Southampton-row, W.C. Telephone 5303 Museum.—Having purchased the designs, jig tools and goodwill of the dynamos, motors, &c., previously manufactured by Messrs. Arthur Lyon and Wrench, Limited, Messrs. Todman, Ryall and Co., Limited, 17, Victoria-street, Westminster, S.W. 1, now carry on the manufacture and sales of this same electrical machinery. The actual manufacture is being undertaken by the Aircraft Manufacturing Company, Limited, Hendon, N.W., in accordance with Messrs. Todman's designs, and solely to their orders. The machines are all tested by Messrs. Todman's engineers at the Air-Co.'s Works, and all parts are interchangeable with the A. L. and W. machines.

THE LATE MR. PETER NISBET CUNNINGHAM.—We regret to have to announce the death, which occurred at Northcote, Uddingston, on the 17th inst., of Mr. Peter Nisbet Cunningham, general manager of the Clydesdale Works, Mossend, of Messrs. Stewarts and Lloyds, Limited, for the last 24 years. Previously to occupying the position with the Clydesdale Works, Mr. Cunningham acted for many years as manager of the Blochairn Works of the Steel Company of Scotland. He then went to the United States, where he superintended the laying down and the starting of the plant of the Middlesbrough Iron and Steel Works, Kentucky. Mr. Cunningham was a past president of the West of Scotland Iron and Steel Institute, a member of the London Iron and Steel Institute since 1868, a member of the Institution of Engineers and Shipbuilders in Scotland, and a member of the Committee on Chemistry and Metallurgy of the Royal Technical College, Glasgow. He was also associated with the Board of Conciliation and Arbitration for the Steel Trade of the West of Scotland, in whose deliberations his counsels had a great influence. Mr. Cunningham was 67 years of age.

THE P. AND O. LINER "NALDERA."

CONSTRUCTED BY MESSRS. CAIRD AND CO., LIMITED, GREENOCK, N.B.

(*For Description, see Page 278.*)

FIG. 12. DIVAN, LOOKING AFT.

FIG. 13. FIRST CLASS SMOKING SALOON.

FIG. 14. FIRST CLASS MUSIC SALOON.

FIG. 15. FIRST CLASS DINING SALOON.

P. AND O. MAIL AND PASSENGER STEAMER "NALDERA."

CONSTRUCTED BY MESSRS. CAIRD AND CO., LIMITED, GREENOCK.

(*For Description, see Page 278.*)

Fig. 2.

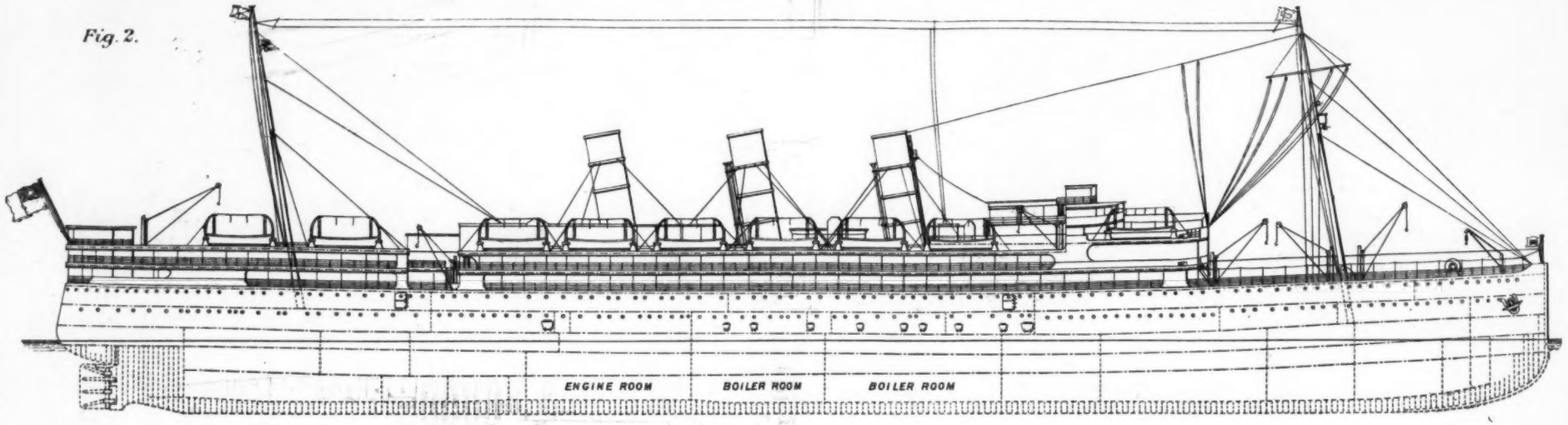

Fig. 3. BOAT DECK.

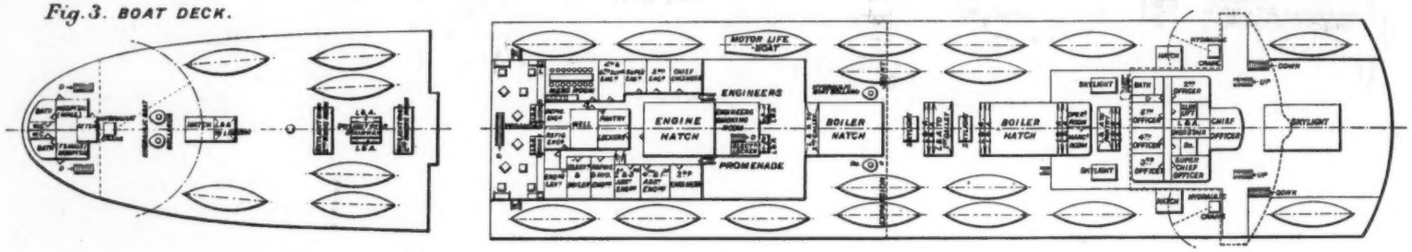

Fig. 4. NAVIGATING BRIDGE.

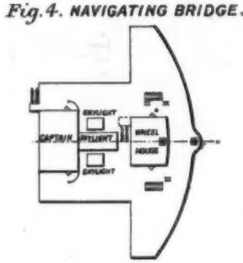

Fig. 5. PROMENADE DECK.

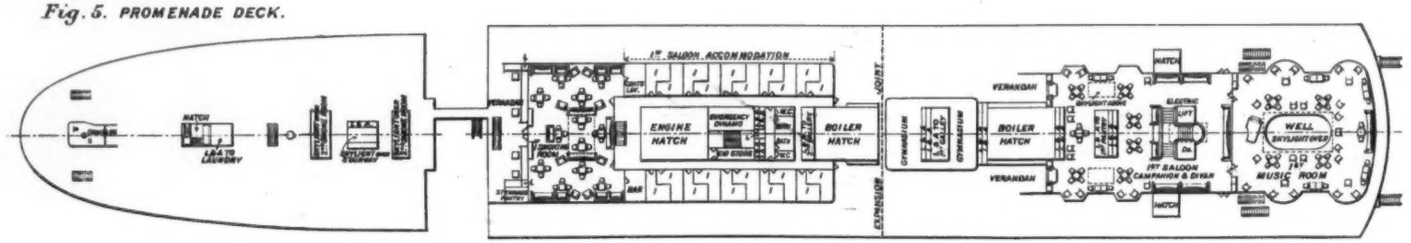

Fig. 6. HURRICANE DECK.

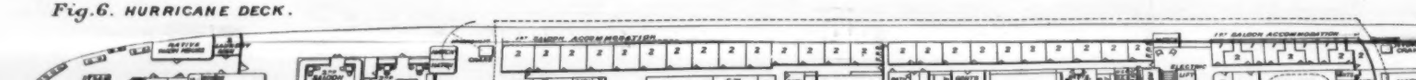

Fig.6. HURRICANE DECK.

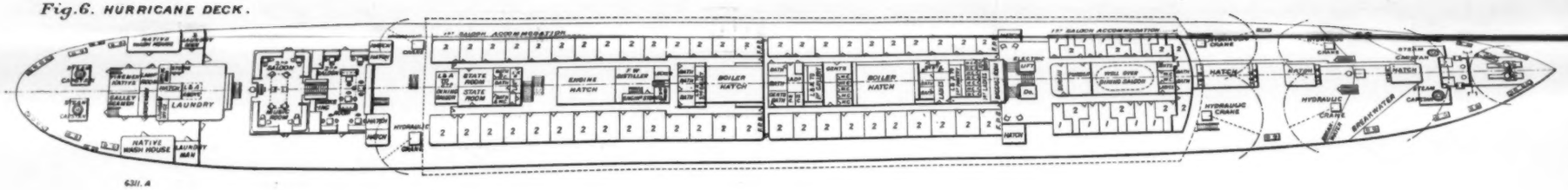

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Fig.7. UPPER DECK.

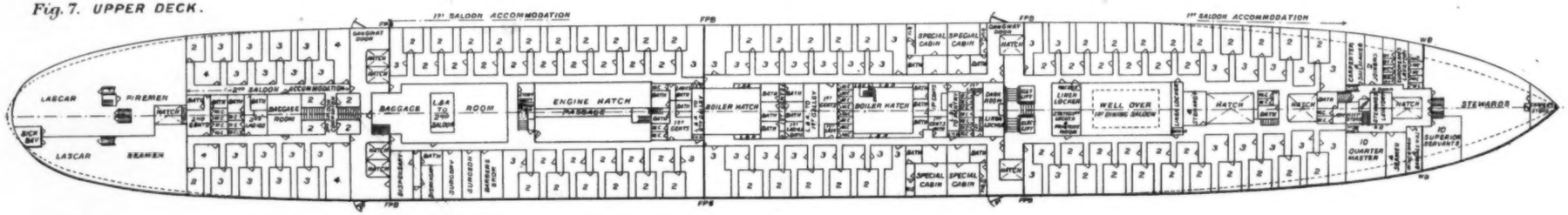


Fig.8. MAIN DECK.

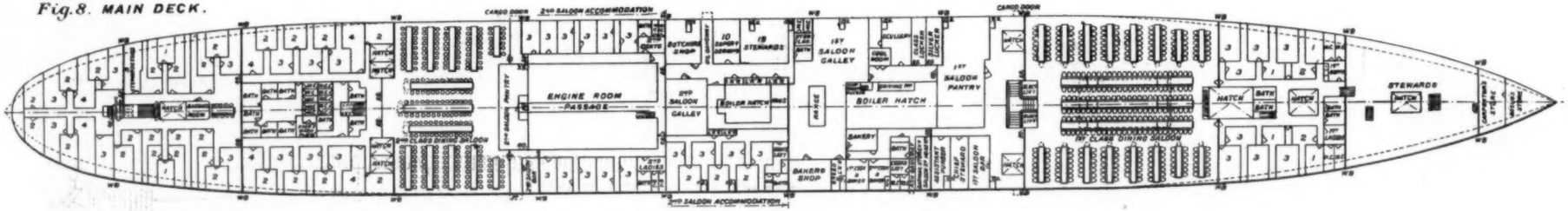


Fig.9. LOWER DECK.

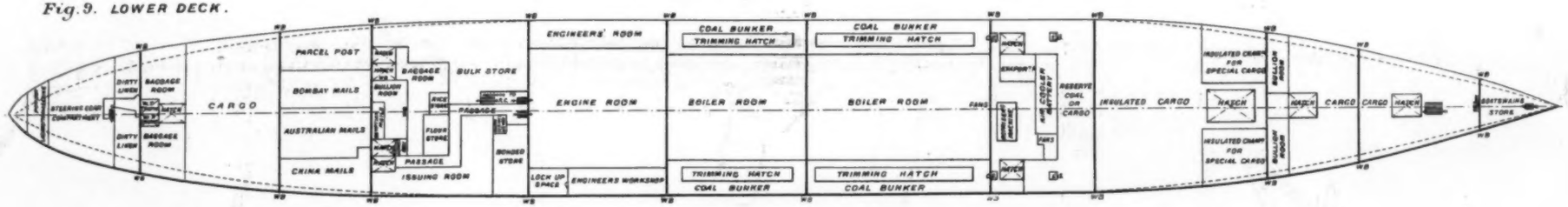
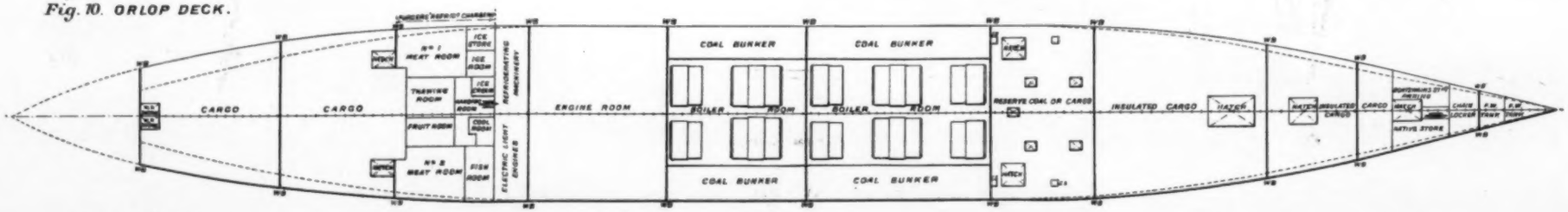


Fig.10. ORLOP DECK.



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Feet 0 5 10 15 20 25 50 75 100 200 Feet

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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With a Two-Page Plate of the P. AND O. MAIL AND PASSENGER STEAMER "NALDERA."

NOTICE.

A few months ago the Proprietors of "ENGINEERING" were compelled to advance the price of this Journal to 1s. per copy, owing to the enormous increases in the cost of paper, engravings and printing, &c. Now higher transport and delivery charges involve a further increase to 1s. 2d. per copy, and this price dated from and included the issue of Friday, April 2, 1920. As the postal rates have been again increased, the price of single copies sent by inland post will be 1s. 2½d. from September 1st.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

ENGINEERING.

FRIDAY, AUGUST 27, 1920.

WAGES MOVEMENTS.

At the recent hearing of the Industrial Court of the claim by the engineering and shipbuilding trades unions for increases in wages, a considerable portion of the evidence brought by the workers' leaders was by way of comparisons between the earnings of various classes of skilled men both within and without the engineering and shipbuilding trades. The earnings of the average engineer were compared with those men who have charge of rolling mills in steel works, with London omnibus drivers, and with others, and it was urged that, relatively, the engineer as regards wages, was in a most unfavourable position.

Supposing that this type of argument is carried to its logical conclusion, it is interesting to reflect how far it leads. Take the steel worker as an example. It is well known that the wages at present being paid to workers in charge of processes in steel works may reach the figure of 30*l.* per week; in fact, recently in a number of Sheffield steel works managers pointed out to their directors that they were earning less than many of the men under their charge. It is a well-known fact that on piece-work it is not uncommon for the workers to be receiving more money than the head foreman in charge of the whole shop, who sometimes is in receipt of more than the manager above him. That this is illogical and offers little inducement to men to gain advancement must, of course, be granted. The wage disparity in the case of various sections and individuals in any industry, district or works is at present the cause of very great discontent. In a measure, it is the outcome of the war and its conditions. Prior to the war there were, of course, many anomalies, but they were the result of conditions which had very gradually developed around industrial growth and were regarded as inseparable from the industry or grade in which they were operative.

During the last five years, movements in regard to wages and costs have been extremely rapid. Some have taken place on a basis which was regarded as just and equitable under pre-war conditions, but which now gives extreme results. So long as industry is in a thriving condition, little movement towards a rationalising of the basis can be expected, although to wait until conditions, if ever, return to a sufficiently near approximation to the pre-war state will be impossible. Such cases for instance as where wages rose and fell with the selling price of the commodity being manufactured, worked well within the limits of variation of such prices and values experienced in the period between the inauguration of the system and 1914. At the present time, however, due to the extraordinary high costs of coal and other raw materials, the selling price has increased out of all proportion to the increases in cost of living, so that the wages earned by these men have been proportionately augmented. This has created discontent on the part of those who received increases of wages only in accordance with the cost of living.

Furthermore, within recent months, large increases of wages have been granted to certain sections of labour due to the extreme shortage of the products with which they deal. Their organisations have taken full advantage of the necessities of the times and of the world shortage resulting from the war, which must be made good. So inconsistent and disproportionate are the rates of wages paid to different and varied classes of labour, that considerable time must elapse before even the greatest of the anomalies are eradicated. Certain it is, however, that if it were conceded that the higher wages at present being paid should be regarded as the standard to which the lower should be raised, then the whole present economic system must fail. It is a levelling-down rather than a levelling-up which must take place, and especially is this becoming imminent where shipbuilding, marine engineering and several other industries are concerned.

The evidence before the recent Industrial Court, to which reference was earlier made, shows that, within the last few months, over 100 contracts for ships have been cancelled. Little new work is at present being placed, and the direct consequences with shipping freights falling and still tending downwards, will be that shipowners will cease to place orders for new ships until such time as the cost of production of ships and the depreciation on the capital outlay bears a reasonable proportion to the probable earning capacity of the vessels. We deem it well to urge full consideration of these points by all concerned.

The sooner trades unionists realise that only upon an economically sound basis can business be conducted without severe detriment to the whole community, the better. If, instead of urging employers to grant still more increases in wages, the engineering and shipbuilding trades unions would exert all their influence upon the coal miners and other producers of raw materials to speed up production, not only would steel be cheaper, and shipbuilding be more economical, but there would be that margin of coal for export purposes which would tend to balance our foreign trade and stabilise our foreign exchange ratio. It would also give the shipping industry a greater degree of certainty of freights, would re-establish vital industries in other countries starved at present for the lack of coal, and would enable commodities, for which we depend on foreign markets, to be manufactured there at less cost, to be brought to this country at lower freights, and to be sold in our markets at a price more advantageous to a reduction in the cost of living. When trades unionists take such a view and forget sectionalism, then they will also have taken the first step towards establishing substantial proofs of their capacity to govern.

To turn next to a consideration of the position of members of the staffs of industries, whose remuneration in general has not increased comparably with the rise in the cost of living. Firstly, it must always be borne in mind that this case is quite apart from others, because of the greater security of tenure of position, the generous nature of bonuses often given, holidays and periods off work due to illness not to be discounted, and other factors.

On the other hand, it is upon the brains of industry that future prosperity most directly depends. One of the lessons taught by the experience of the war was that increased confidence may be placed upon the fact that where scientific ingenuity and attainment are concerned, we can expect to take the first place, provided the necessary stimulus is present. During the war, when once the conditions to be met were understood, and the brains of the country were organised to concentrate upon the problems formulated by growing experience, solutions ingenious, apt, and scientifically in advance of those of any other nation in arms, were generally forthcoming.

As time advanced pre-war experience in the engineering of war gradually assumed less and less significance, and the work of our own designers and constructors showed the greater ascendancy. In making these statements, significance must be given to the fact that we were placed in a favourable position by virtue of having a greater supply of raw materials than was available to most other forces with whom comparison is being made. However, the general statement holds good. The same ingenuity

and degree of scientific attainment are required by the problems of reconstruction now being undertaken, and are essential to a maintenance of steady progress. It is earnestly urged that this issue shall not be overlooked and that industry shall give to brains their due and fair measure of reward; a short-sighted policy in regard to this matter would seriously react to the detriment of the future.

THE INDUSTRIAL REVIVAL OF BRAZIL.

Among the countries that have benefited commercially and financially by reason of the war, Brazil occupies a very favourable situation. In 1914 the country's industrial and economic position was not good. Prices of Brazilian products had fallen and her international trade had declined. Her foreign borrowings had increased by no less than 190,000,000*l.* during the preceding seven years, and her Federal Customs revenue had declined to an alarming extent. Many local textile and other factories had closed down altogether, or had reduced their working hours, through lack of capital wherewith to purchase raw material, and a marked general depression was everywhere in evidence.

During the first year of the war there was little general improvement. Some revival in local industries took place towards its close, and the rate of foreign exchange became rather more favourable. But it was not until 1916 that Brazil really commenced to reap any benefit from war conditions. During this year her imports increased and commanded higher prices, while new products had begun to be exported. A number of new industries had sprung up, existing factories were worked to the limit of their output, and new factories were built. The industrial and financial revival of Brazil had commenced. In 1917 the trade expansion which had made its appearance during the previous year was continued and accelerated, and although the entry of Brazil into the war during October of that year to some extent embarrassed her commercial activities it did not suffice, owing to the country's favourable geographical position, materially to check progress. During the remainder of the war, and during the period that has since elapsed, the development of Brazilian industries has been maintained, her trade expansion has continued and her financial resuscitation has persisted.

In 1913 the total value of Brazil's imports amounted to 67,166,000*l.*, and her exports to 64,849,000*l.*, giving an adverse trade balance of 2,317,000*l.* For the first nine months of 1919 the total value of her imports was 57,697,000*l.*, while her exports had increased in value to 94,051,000*l.* At the time of writing complete figures for the year 1919 are not available, but on the assumption that both exports and imports remained the same for the last three months of the year as for the other nine, Brazilian imports will have increased by only a little more than 7 per cent. in the six years 1913 to 1919, while her exports will have increased by about 81 per cent. during the same period. In 1913 Brazil was economically in a precarious position. Her vast natural resources were largely unexploited owing to lack of the necessary capital to overcome the difficulties that had to be surmounted in order that they might be developed. To-day the country is economically sound, and is in a vastly improved financial position, while as a result of these improved conditions the exploitation on a much larger scale of her natural resources may be confidently anticipated.

The potential wealth of Brazil is enormous, and in view of the country's present prosperous condition it is probable that the realisation of this wealth may be one of the outstanding features in the commercial world during the coming years. Apart from her very considerable agricultural industries and the wealth of her forests, Brazil is the possessor of important mineral deposits. Of these the gold and diamond mines have alone been extensively worked. Manganese, of which there are almost inexhaustible quantities, has been mined on a large scale, and has formed one of the important exports of the country. But in spite of their importance existing operations have done little more than point the way to operations on an infinitely larger scale. Iron ore, with which the country is particularly well endowed, has not been mined to any considerable extent on account of the inaccessibility of many of the richest deposits, and the same factor has prohibited the extensive working of the coal measures. There are considerable deposits of coal in the Southern States, some of which have been developed to a certain extent. The coal, however, is not of good quality, and on combustion leaves a high percentage of ash. Some tests, however, recently carried out on the Central Railway of Brazil with pulverised Brazilian coal are said to have been quite satisfactory, and it is possible that in future the coal-mining industry of the country may assume an enhanced commercial importance as a consequence. Large supplies of coal are available from purely surface workings. In striking contrast to the indifferent quality of the coal is the quality of the iron ore. This is not only very plentiful, but in many cases it is also extremely rich. The iron ore deposits in Minas Geraes alone are said to contain 3,000,000,000 tons of mineral, the proportion of metal averaging some 50 per cent. It is very doubtful if any country possesses larger deposits of iron ore than does Brazil, and it is probable that the mining and working of this metal may eventually become the principal industry of the country.

The great difficulty that stands in the way of a more extensive exploitation of the natural resources of Brazil is the matter of transportation. So far as maritime communication is concerned the country is fairly satisfactorily placed. But considering her size and population the railways are inadequate. Only some 18,500 miles are at present in operation, much of it being single track and all of it indifferently equipped and short of rolling-stock. The topographical difficulties which the railway engineer meets with in most parts of the country, together with the high price of material, renders the cost of construction excessive, and necessitates the imposition of high freight rates. These in turn militate against the commercial development in the more remote districts of industries which involve the railroad transport of commodities having a relatively low value per ton, such as coal and iron. But in the case of the latter the richness and abundance of the ores may so cheapen the process of smelting as to render highly profitable the exploitation on a large scale of deposits which are not too favourably situated from the geographical point of view. This factor of transport charges is one which should be taken into account in estimating the possibilities of the development of the iron and steel industries in Brazil. That the Government has faith in such possibilities is, however, evinced by the fact that in March, 1918, a decree was issued authorising Government mortgage loans to all concerns engaged in the manufacture of iron and steel up to the amount of capital invested in the installation of the plant.

Another factor which may have an important bearing on the industrial future of the country is the possession of almost unlimited water power. This is estimated at 50,000,000 h.p., of which only a small fraction of 1 per cent. has so far been utilised. Fuel oil, which is found in considerable quantities within easy reach of the seaboard, and which is said to have a high calorific value, may also have an important influence on the industrial situation.

In view of the fact that Brazil has, during the war, assumed a position in international commerce which she did not formerly occupy, and of the prospect of her rapidly improving on that position during the next few years, the trade relationship of this country with Brazil is worth consideration. In 1913 Brazil imported from us about 16,000,000*l.* worth of goods, coal being the principal single item, and engineering products of various descriptions being second in importance. During the same year her imports from Germany amounted to 11,750,000*l.*, engineering and scientific products forming an important proportion of this total, while her imports from the United States were worth 10,500,000*l.* During the war imports from Germany ceased, owing to the unwelcome attentions of the British Navy, while our own exports to Brazil decreased to 11,200,000*l.* in 1918, a figure which was barely reached last year. On the other hand, imports from the United States rapidly increased during the war, the total value for 1919 approximating 36,000,000*l.* They included such significant items as motor cars and spare parts, railway rolling-stock, electrical machinery, hardware and cutlery, leather belting, tin plates, wagons and agricultural machinery, and considerable quantities of manufactured iron and steel. In other words, the United States has been successful in capturing not only the temporarily-vacated German market, but also a considerable share of ours.

American trade in Brazil has been carefully fostered during recent years by a large amount of advertising and propaganda work. In spite of this, however, the British enjoy a far higher commercial reputation throughout the country than any other nation, and if use could be made of this reputation by the adoption of modern and intensive selling methods the manufacturers of this country might not only get back all the trade which has been lost as a result of war conditions, but might share largely in the increased business which will accrue during the coming years from the further industrial development of the country.

In order to do this, however, it is essential that home manufacturers should have stocks of machinery on the spot. The average Brazilian purchaser will always buy what is immediately available in preference to waiting for some months for the execution of his order, even if the machinery offered is not exactly what he wants. Standard types of machinery should therefore be stocked ready for immediate sale. Carefully organised advertising should also be adopted if successful competition with United States exporters is to be attained. There is plenty of room for British engineering products in Brazil, and for the establishemnt there of new British firms. The extension of British enterprise in this country promises to prove a lucrative investment for the firms who recognise the possibilities of the Brazilian market, and who go to work upon the right lines to realise such possibilities.

FLOODS.

The destruction of the town of Louth by an extraordinary flood in the River Lud, and the heavy falls of rain all over this country during this year serve to bring to mind the great intensity of rainfall in the tropics. In India, where, as Blandford says, it never rains but pours, falls of 3 in. to 4 in. in an hour are not rare, and last for 2 hours or 3 hours in succession. Calcutta has recorded 4 in. in 1½ hours, and 12 in. within 3 hours. Bombay has had rainfalls of 4½ in. in an hour. In Madras 17 in. fell in 12 hours, and 1·2 in. has been recorded in ¼ hour. In Nagpur, Central India, where the rainfall is scanty, 3½ in. has been recorded in 1¼ hours.

At Louth, on Saturday, May 29 of this year, rain began to fall at 5 p.m., and by 5.30 it was falling in torrents. The intensity of the rainfall at Hallington, in the centre of the catchment basin of the Lud above the town of Louth, is stated to have been about 4·7 in. in 2½ hours, and it is probable that the rain fell with the same intensity all over this portion of the basin, some 20 sq. miles to 30 sq. miles in extent. The water in the river is stated to have risen 2 ft. in 10 minutes, and reached its maximum height about midnight of the same evening.

The catchment basin of the Lud above the town of Louth is fan shaped, with the handle of the fan at Louth; the country has a fall of over 300 ft. in a few miles from the Wolds to the town; and the nature of the basin is described as chalk hills cultivated with large farms, likely to give a heavy run-off when saturated. The heavy rainfall, combined with the steep slope of the catchment basin, must have brought every tributary of the river in full flood almost at the same time into Louth, the handle of the fan, so much so that the waterway of the river was insufficient to carry off the discharge of the river, the waters sweeping over the river banks, and flooding the town. It is possible that the canalisation of the river below Louth reduced the slope of the river or its hydraulic gradient, with the result that the flood was not carried away as

fast as it came in, resulting in the heading up of the water in the town.

The flood at Louth resembles that at Eri Mile Creek, Isle Bay, U.S. The basin above Lake Eri has a sandy, gravelly soil underlaid by a slate formation resulting in a high rate of run-off when saturated; the general level of the country being some 500 ft. to 700 ft. higher than the level of the lake, and the fall of the river for 2 miles above the town being about 1 ft. in 100 ft. The rainfall was reported to be 5·77 in. from 3.30 in the afternoon to 5.30 of the next morning, the rainfall in the hilly portion of the river basin being estimated at 40 per cent. greater than that registered in the town. The greatest intensity of the rainfall was 1¼ in. in ½ hour. The run-off or maximum flood discharge was estimated to be 11,000 cusecs from a catchment basin of 11 sq. miles, or equivalent to a maximum rate of run-off of 1·56 in. per square mile of catchment per hour; or over 50 per cent. of the greatest intensity of the rainfall on the basin.

The River Musi, in Hyderabad, Deccan, came down in an abnormal flood in September, 1908, and caused a considerable amount of damage to the town of Hyderabad. The maximum rate of the flood discharge was estimated to be equivalent to a run-off of 0·75 in. per square mile per hour from its catchment basin of 862 sq. miles, a very high rate of run-off for so large a basin.

The River Charges, Panama Canal area, above Bohio, having a drainage area of 700 sq. miles, with a soil composed of limestone and trap, and being also wooded, brought down a flood equivalent to a run-off of 0·25 in. per square mile per hour—considerably less than the flood intensity of the Musi.

Abnormal floods of the nature described above occur at periodic intervals of time, and it is one of the most difficult problems for a civil engineer to prognosticate the frequency of such floods, to design works to prevent or mitigate the damage and destruction caused by them and to decide whether the circumstances are such as to justify the expenditure necessary to carry out such works.

ECONOMY IN THE USE OF COAL.

Even when normal conditions are restored, we cannot expect to obtain coal at anything like pre-war prices. We shall accordingly be compelled—willingly or unwillingly—to economise. In the past, we have as a nation been far from free from reproach concerning the use made of our coal. Much of this waste and extravagance was, however, unavoidable in the very nature of things. The pioneer has inevitably to waste resources for which his successors may mourn; but if there had been no pioneers, there would have been no successors, and if we had refrained from using our coal until we had learnt the most economical methods of so doing so these methods would never have been devised. Nevertheless, practices pardonable in our past industrial development have lingered on when no longer justifiable, and would continue to do so indefinitely could coal still be obtained at pre-war prices. The note of alarm was sounded shortly after the outbreak of the war, and in 1916 the British Association appointed a committee to make a thorough investigation into the question of fuel economy. The third report just issued is largely concerned with statistical matters, and attention is drawn to the fact that the methods of compiling official statistics vary from country to country. It is suggested that an international conference should be summoned, to deal with this question. As matters stand the figures given for output, for the number of men employed, and for mining accidents are not comparable for different countries. In England, for example, an accident is considered fatal if it results in death within a year. In Belgium, only if death occurs within 30 days. Again, in this country a non-fatal accident must be reported if the victim is disabled for more than 7 days. In France the corresponding term is 20, and in Belgium the accident is not recorded unless it results in permanent disability, partial or complete.

The committee report successful experiments at Skinningrove on the production of alcohol from debenzolised coke-oven gas, which contains from 2 per cent. to 2·5 per cent. of olefines, and it is these which are converted into alcohol. It is stated in the report that, on a large scale, 1·6 gallons of absolute alcohol could be recovered per ton of Durham coal coke, and that our by-product coke ovens should be able to supply an aggregate of 24,000,000 gallons per annum of absolute alcohol. Exception is taken in the report to certain features of the "Gas Regulation Bill," which substitutes a calorific standard for the luminosity standard previously in use. As originally framed the Bill fixed a limit to the proportion of incombustible constituents permissible in the gas supplied. The matter is of considerable importance since, for example, the presence of carbon dioxide cools the flame and thus renders the gas less suitable for lighting with mantles or for use in gas fires. The restriction in the amount of incombustible ingredients was, however, deleted whilst the Bill was in committee, and the matter left for subsequent decision on the basis of a proposed Board of Trade inquiry. The Board of Trade is also charged by the Act with fixing the percentage of carbon monoxide that may with safety be permitted. This year the committee have no progress to report on the matter of low-temperature carbonisation of coal, nor on another important subject they have under review, viz., the thermal efficiencies attainable in different uses of fuel. The question of the possibility of improved method of mining our coal does not seem to be engaging the attention of the committee. The late Sir William Ramsay, it will be remembered, maintained that it was practicable to gasify thin coal seams *in situ*, a feat which would enormously increase our fuel reserves and might greatly reduce costs. His scheme did not commend itself as practicable to mining engineers, but some experiments were made, which, however, were impeded by his ill-health and brought to an end by his death. In view of present developments, it might be well if the committee would add to the list of investigations that they have now in hand a thorough inquiry into the practicability of Sir William Ramsay's schemes, forbidding though the attendant difficulties appear.

THE BRITISH ASSOCIATION.

Old members of the British Association who had attended the 1891 meeting at Cardiff will not much have been helped by their geographical reminiscences in finding their way to the various Association rooms during the present meeting. A new Cardiff has grown up since the City Council acquired Cathays Park from the Marquess of Bute, and when the great project for utilising the site has been fully carried out, Cardiff will possess a group of public buildings unrivalled in the United Kingdom. The Assembly Room of the City Hall makes a splendid Reception Room, and all the sections are well and adequately quartered either in the Technological College or in the University College; Section G—that devoted to engineering—has a building for itself, as we stated in our article a fortnight ago, and enjoys the hospitality of the South Wales Institute of Engineers. The Handbook* to Cardiff and Neighbourhood, prepared for the British Association visit by Mr. Howard M. Howlett and various experts, recalls in its compass and contents the good pre-war days and the 1891 Handbook; of late, the Association handbooks have naturally dwindled in size. The needs of economy have also affected the journal. Formerly a new journal, giving the sectional programmes, was issued every morning. Now one journal is printed for the whole meeting, notice of subsequent alterations being given in the Reception Room. The journal also embodies short abstracts of some papers which previously would have been printed on separate sheets.

The arrangements for the excursions and visits to works are mostly in charge of the sectional officers. Some sections meet in the afternoons as well as in the mornings. But Saturday is so far left free for two general excursions, the one to the Wye Valley and Tintern, the other to Weston-super-Mare, Glastonbury, Wells and Cheddar.

The sectional proceedings were opened on Tuesday morning. The President of the Association, Professor William A. Herdman, C.B.E., D.Sc., LL.D., F.R.S., of Liverpool University, delivered his address on Tuesday evening.

Oceanography and the Sea Fisheries.

The subject which Professor Herdman had chosen for his address is peculiarly his own. Up till last year Professor Herdman, General Secretary of the Association in the years 1903 to 1919, had been Professor of Natural History and Zoology in the University of Liverpool. Last year he endowed a chair, the first of this kind in the kingdom, for oceanography and sea fisheries in his own university, agreeing to occupy the chair till October this year and stipulating that the teaching should bear close relation to the sea fisheries of Lancashire and the ocean trade of Liverpool. Thus he linked academic science directly with local industry, if the industry mentioned can be regarded as strictly local. This was by no means Professor Herdman's first work for fisheries. He had established a fishery table at Liverpool and combined with it the biological station at Port Erin, Isle of Man; the dredging expeditions which he arranged in connection with several British Association meetings were only part of his routine work. The Isle of Man Fishery Board and the Lancashire and Wales Sea Fisheries to which he referred in his address—he did not allude to the other facts we just mentioned—have been in constant touch with the university. Now new curricula have been drawn up, not only for students of oceanography and sea fisheries, but also for those who are commercially and administratively interested in these important branches of applied science. The new curricula will be welcomed. It has also been said that new degrees had been created in connection with the curricula. This would not be surprising in our days when titles, degrees and decorations flourish as never before. But that is a misunderstanding; Liverpool has not codified any new degrees. The degrees of B.Sc. and B.Com.Sc. (Bachelor of Commercial Science) which Liverpool is granting are not new degrees, but they can be acquired by studies of the new curricula.

When Sir William Huggins took the chair at Cardiff in 1891, he dwelt upon the progress of a new branch of science, astronomical spectroscopy. If astronomy be the oldest science, Professor Herdman spoke as representative of the youngest science, oceanography, which could not grow up before physics, chemistry and biology had attained a relatively mature development. Professor Herdman designated as father of oceanography the late Sir John Murray, who had declined nomination to the Presidency of the Association because his maritime explorations—he made his last expedition when over 70 years of age, together with W. J. Hyort in 1912—had not left him time. Murray introduced the term "oceanography" in 1881; Alexander Agassiz had, before him, written of "thalassography." But Pytheas passing, in the fourth century B.C., through the pillars of Hercules into the Atlantic and to the British Seas, was in a way an oceanographer, as Edward Forbes was a modern pioneer of it. On the instigation of Forbes the Dredging Committee of the British Association was established in 1839—the naturalist's dredge had first been used by the Dane, O. F. Müller, in 1799—and the British Association has indeed inspired and fostered new lines of research in this field as in many others. That the Government fitted out the Lightning in 1868 and the Porcupine in 1869 for scientific maritime exploration was partly due to Forbes and to the British Association. The chiefs of these expeditions, Wyville Thomson and W. B. Carpenter, were again the scientific leaders of the "Challenger" expedition in 1872–76. The final reports of that expedition were, after Thomson's death, edited by Sir John Murray.

These and the later expeditions disproved many a fact again that the earlier explorations seemed to have established. The oceanographer has literally to grope in the dark for samples that may be at the other end of a wire 10 miles long, as Professor Herdman put it. Thus Edward Forbes considered that the deep sea must be devoid of life; Agassiz thought that the medium depths would be poor in life at any rate, whilst it is now believed that abundant life extends down to the greatest depths known, of about 6 miles. Sixty years ago cable

* A 16s. publication of 314 pages, with maps, printed by Messrs. William Lewis, Ltd., Cardiff.

dredgers brought up a mysterious mud from the bottom of the Atlantic, in which Huxley and Haeckel discovered an exceedingly primitive protoplasmic organism; by 1879 Huxley had to admit that "the bathybius had not fulfilled its promises"—it turned out to be essentially calcium sulphate.

The problem of the propagation of the eel is not completely solved yet. We know that the maturing eels descend our rivers and travel far out into the sea where, beyond the Azores, in depths of 2,000 fathoms, Johannes Schmidt actually found the smallest larvæ, only ¼ in. in length, which when bigger were known as the tapelike transparent *lepiocephalus* subsequently turning into "elvers." But the actual spawning of eels has not yet been observed. Their propagation seems to require deep water not colder than 7 deg. C., of high salinity. Now Otto Pettersson observed bottom waves of high salinity in the Kattegat; the bankwater seemed to be sucked into the Swedish fjords, bringing plenty of fish with it.

Such submarine waves, currents, temperature, &c., are certainly very important for the planckton, the floating life of the sea (vegetable and animal), the staple food of herrings and mackerels, &c., and also of the more fastidious French sardines which select their diet. It is not certain that plankton is more abundant in temperate than in tropical waters. The yellow *alga trichodesmium* (the "sawdust" of Cook), common in the Red Sea, may cover immense areas of the Indian Ocean. Warmth accelerates reaction and development, chemical as well as biological, which cold inhibits. But heat also favours the multiplication of nefarious bacteria which do not spare low organisms. The massive calcareous shells of molluscs and the vast deposits of calcium carbonate by corals are characteristic of the tropical seas, whilst the larger animals of the cold seas are mostly soft-bodied, and the diatomaceous ooze of the Antarctic is siliceous. There, again, however, bacteria, the bacillus *calcis* of Thomas Drew, which precipitates calcium salts on the Florida coasts, may play a part. The alkalinity of the sea water is another important factor. The warm water of the Gulf Stream is more alkaline than the cold water of the Labrador current, and near the Isle of Man the alkalinity has a maximum in April and a secondary maximum in autumn, suggesting seasonal changes that coincide with the abundance of plankton.

In order to control these factors quantitative estimates of the numbers of organisms, fish eggs, &c., were first made at Kiel. Hensen passed the water through nets; Lohmann and others of his colleagues tried filter paper and the much finer pores of the beautiful filters spun by the pelagic *appendicularia* for the capture of its own food; Johan Petersen uses a bottom sampler to bring up mud or sand from the sea bottom; Dr. E. J. Allen, of the Plymouth Marine Laboratory, dilutes very small samples of sea water with sterilised water treated with a nutrient solution, and then counts the organisms developing. All these estimates depend much on the accidental suitability of the square metre of sea surface selected, and thus upon weather and current. Yet the results show a certain uniformity, and it seems clear that an area of the sea may be more productive of food than a similar area of pasture or crops on land. Thus systematic study will repay itself. But lecturing at the Royal Institution in 1847, Edward Forbes had occasion to blame the Government strongly for their mismanagement of submarine research and the sea-fishery question, and little is done even now. The whole population of these islands owes much to the sea. In concluding his address, Professor Herdman asked "What are you doing at Cardiff to advance our knowledge of the ocean?"

To this question, however, the Lord Mayor of Cardiff, Councillor G. F. Forsdike, made no definite answer, when welcoming the Association, and proposing a vote of thanks to the President. Referring to the atmosphere of unrest with which he had had to deal—the strike of the Corporation employees—he remarked that the man of Cardiff was more interested in having herrings fresh on his breakfast table than in what the herring lived on. But the merchant princes of the district should not fail to support a work of such truly national importance. Sir Oliver Lodge seconded the vote of thanks in an equally happy speech.

We should not omit to mention that Sir Charles Parsons, in vacating the chair, dwelt upon the sad losses the Association had quite recently sustained in the deaths of Professor Perry, the Treasurer, Sir Norman Lockyer, a Past-President, and Mr. H. C. Stewardson, since 1873 the faithful Clerk and Assistant Treasurer to the Association. Professor T. H. Turner announced that 1,317 members had so far entered their names. We now pass on to our account of the sectional proceedings, beginning with Section G, Engineering.

Section G.—Engineering.

The Engineering Section met in the lecture hall of the South Wales Institute of Engineers on Tuesday morning, and the proceedings commenced with the reading by Professor C. F. Jenkin, C.B.E., of his Presidential Address of the section. There was, however, a very poor attendance, only from 20 to 30 members being present. The address, which we reprint on page 290 of this issue, was naturally not open for discussion, but, in proposing a vote of thanks to Professor Jenkin at its conclusion, Professor Henderson mentioned that in the older branches of engineering it was possible to cover ignorance by employing large factors of safety, but this was not possible in aircraft design, and hence the necessity for accurate knowledge of the strength of materials. The speaker was not, he said, an authority on the subject himself, but he had little doubt that the address would have produced a most valuable discussion had that been possible. In any case Professor Jenkin was to be congratulated on having obtained permission to publish the very useful data included in the address, which would be of the utmost value to engineers. The vote of thanks was seconded by Professor F. C. Lea, who emphasised the point that, what was required to increase our knowledge of the subject of strength of materials, was to carry out experiments of a fundamental nature as Professor Jenkin had done. Professor Lea thought that engineers were inclined to neglect the assistance they might derive from the co-operation of mathematicians and experimentalists, and this appeared to him to be rather unfortunate as the engineer's own knowledge of mathematics was apt to become rusty.

Testing Materials at High Temperatures.

After the vote of thanks had been carried with acclamation, Professor Jenkin called on Professor Lea to read his paper on testing materials at high temperatures. We reproduce this paper on page 293 of this issue, so that we may at once proceed to deal with the discussion. Professor Jenkin, in opening the discussion, referred to the trouble experienced with the exhaust valve springs of rotary engines for aeroplanes. These springs, he said, had broken in large numbers, and, on investigation, it had been found that the strength of the steel from which they were made was reduced to one-half its normal value at the temperature to which the springs were subjected in working.

Professor Hudson Beare, the next speaker in the discussion, said the author had pursued a valuable line of investigation that was of great importance in connection with the design of internal-combustion engines. He hoped that other workers would take up the subject and proceed on similar lines to Professor Lea. In connection with the fire protection of ferro-concrete structures it was extremely interesting to know to what extent the steel was protected by the concrete from the high temperatures to which it would otherwise be directly exposed. Referring to the matter of cracking of the concrete during cooling, which Professor Lea had stated was worse when the cooling took place in the open air than when the cooling occurred in the furnace, Professor Beare pointed out that, in the ordinary way, after a fire the concrete would be cooled by a jet of water, and he inquired what would happen then. He expected that the concrete would scale off and expose the steel to the action of the flame, which would not be immediately extinguished. This would be serious, especially in the case of columns, and might lead to the collapse of the structure. He thought experiments in this matter might well be carried out in the laboratory, as some full-size experiments carried out abroad at considerable expense, had not produced much useful information.

Professor J. T. MacGregor-Morris, who followed, said he wished to refer to one or two electrical matters. In connection with Fig. 2 of the paper (see page 293 of this issue) which showed a potentiometer method of measuring the E.M.F. of the thermo-couples, he asked what was the use of the fine adjustment resistance in series with the galvanometer. Continuing, the speaker said the information given as to the design of the furnaces was most useful, but he would be glad if Professor Lea could add to it the size and the approximate length of the wire used. He would also like to know the volts, amperes and watts used by the furnaces.

Mr. C. E. Stromeyer, called on by Professor Jenkin, said he had no questions to ask, but he thought the case of the explosion of a cast-iron steam pipe, which had come to his notice, had a bearing upon the subject matter of the paper. The pipe, which, he said, had been in use for some thirty-five years, first at a pressure of 145 lb. per square inch and afterwards at 120 lb. per square inch, had suddenly burst, having split longitudinally throughout the whole of its length. The interesting feature, however, was the fact that the fracture did not close up after the explosion, but remained open for about ¼ in., indicating a very severe compressive stress on the inside of the pipe and a tensile stress on the outside. He asked what was the cause of the compressive stress.

The only other speaker on this paper was Professor W. H. Watkinson, who asked what were the melting-points of the various alloys tested. There must, he said, be some relation between the melting-points and the plasticity indicated by the curves. Referring to Fig. 17 of the paper (see page 295 of this issue), which showed how the tensile strength of mild steel varied with the temperature, the speaker pointed out that the maximum strength occurred in the neighbourhood of the temperatures used in steam boilers which, he said, was a particularly fortunate circumstance. In connection with the fire protection of ferro-concrete structures, he suggested that steel tubes might be used instead of rods, water being caused by automatic means to circulate through the tubes in the event of fire, so that the steel would not be overheated. He did not think the cost of such an arrangement would be excessive, and it would certainly save the structure from collapse.

Replying to Professor Beare, Professor Lea stated that he had not yet carried out experiments on the effects of suddenly cooling concrete. He had, however, seen a number of experiments carried out on large slabs which had been exposed to a temperature of 1,800 deg. F. for about 4 hours. A jet of water directed on to the slabs had caused considerable damage in some cases, but in others the damage was only slight. He intended later on to try the effect of quenching the specimens suddenly. In reply to Professor MacGregor-Morris, Professor Lea explained that the fine adjustment shown in Fig. 2 of his paper was incorrectly designated as such. It was actually used to protect the galvanometer during the process of obtaining the first rough adjustment, and was afterwards cut out to obtain the final correct reading. He could not remember the exact size and length of the resistance wires used for the furnaces, but he thought that, in the large furnace, it was of about 12 gauge, and in the small furnace about 18 gauge. The voltage used was generally either 220 or 110, and in designing a furnace they first determined the resistance of a certain length of wire, and decided upon the maximum current to be employed, making the length of wire as great as possible consistent with the current to be carried and the voltage available. In order to avoid the use of external resistances he now employed a direct-current generator, the field of which could be varied so as to produce a terminal voltage ranging from 250 to 10. The temperature of a furnace could thus be regulated without waste of energy, by adjusting the applied voltage. He agreed with Professor Watkinson that it would have been useful to have given the melting-points of the alloys used, but he had not thought of this in preparing his paper. The metals and alloys were, however, all of standard qualities, the melting-points of which were well known. With regard to the

use of water-cooling pipes in ferro-concrete structures, he thought some trouble might be experienced owing to corrosion, but the suggestion was, for all that, a valuable one. He thanked the meeting for the reception given to his paper.

Professor Jenkin then announced that the next paper on the programme, viz., that by Mr. Eric Jones, on "Experiments on Impact Torsion," had been withdrawn owing to the illness of the author, and he called on Colonel R. E. Crompton to read his paper on the "Cutting Edges of Tools."

The Cutting Edges of Tools.

After reading his paper, which we reproduce on page 292 of this issue, Colonel Crompton apologised for what he described as the crude form in which it had been presented owing to the short time at his disposal. Professor Jenkin, rising to open the discussion, said no apology was necessary from Colonel Crompton, as the paper was a particularly interesting one. He asked the author to define exactly what was meant by the cutting angle, as all cutting edges were really rounded if examined at a sufficiently high magnification, and also inquired the meaning of the sawing action referred to in the paper. Professor Jenkin mentioned that he had recently seen a new form of blade for a reaping machine in which the knives were formed with serrated edges. These blades, he said, retained their form without sharpening.

Mr. C. E. Stromeyer, the first speaker, referred to the covering iron used with a carpenter's plane. He thought the object of this iron was not so much to protect the upper surface of the plane iron from wear as to cause the shavings to curl up. He had used planes both with and without covering irons, and, in the latter case, had found that there was a tendency to plough up the wood and leave a rough surface. With lathes and other similar tools, the upper surface was certainly worn away as well as the under surface, and evidently some metal which would resist this wear was required. At first sight it would appear that manganese steel, which was but little affected by abrasion, would be excellent for such tools, but actually it was one of the worst materials for the purpose. The question of the edge itself had to be considered, and much depended on the actual finish of the edge. The best cutting edges, he thought, were those produced on certain instruments used in ophthalmic surgery, and these edges were extremely difficult to produce. He had recently used a glass scraper to finish the surface of a mahogany table, and had been surprised at the polished appearance of the small chips produced in the process. This, he thought, was due to the fact that the glass formed an almost perfect cutting edge.

Dr. W. H. Owens, the next speaker, referred to the subject of razor edges and pointed out that, after the edge had been ground as finely as possible, it was necessary to strop the razor on leather or some other similar substance. He inquired what happened during the process of stropping. Were serrations produced or were they removed? With regard to carpenters' planes the practice was to keep the covering iron as close as possible to the cutting edge in a smoothing plane, and to leave more of the cutting edge exposed in the case of a jack plane. He also asked what was the limiting thickness of a fine cutting edge and what happened in cutting.

Professor Lea, the only other speaker on the paper, suggested that in stropping a razor amorphous material was produced, and, as glass was an amorphous material, this fact might account for the excellent cutting properties of the glass scraper referred to by Mr. Stromeyer.

In his reply, Colonel Crompton explained that, in his experiments, the finest discs had been used for rough grinding and the cutting edges had been finished by lapping on a cast-iron surface plate with fine crocus. By this means the cutting angles were maintained almost up to the edge, though it was not possible to do this exactly. He had no doubt that the results obtained by careful lapping with diamantine would be superior to those with any other abrasive material. Burnishing the cutting edge certainly had a most important effect with fine tools, and even with lathe tools for fine cuts. He had been able to strop safety razor blades by merely passing the edge between the finger and thumb, but he was unable to explain what took place during the process, as no difference in the blade before and after treatment could be detected by microscopic examination. With regard to the question of the effect of the covering iron in a carpenter's plane, Colonel Crompton stated that he had taken a smoothing plane, sharpened it up as well as possible, and then planed a piece of teak for 2 minutes or 3 minutes. After this the iron, examined under the microscope, showed grooving on the upper edge and slight rounding on the lower edge, sufficient, at all events, for the actual edge to break away. The grooving was quite close to the upper edge and would be ground away when the iron was sharpened up. In reply to Dr. Owens he was unable to say what was the limiting thickness of a cutting edge, but he was of opinion that the limit would be finer with high-class modern cutting steels than would be possible with commoner varieties.

After Professor Jenkins had thanked Colonel Crompton for his paper the meeting adjourned, and, in the afternoon, the section visited the Bute Docks of the Cardiff Railway Company. With the further meetings on Wednesday, Thursday and to-day, we shall deal next week.

(To be continued.)

NOTES.

Economic Reconstruction.

It is a commonplace of biology that the less highly differentiated a living being may be, the more readily can it repair serious injuries. A snail will survive and completely recover from mutilations which would be fatal to a mammal. The presidential address of Mr. J. H. Clapham to the economics section of the British Association suggests that a similar rule holds with the political organism. He states that France, though she issued from the Napoleonic period as a defeated country, recovered much more quickly than did England which was victorious. England, it is true, came out of that conflict with a war debt of 848,000,000*l.*, whilst that of France did not reach 200,000,000*l.* till 1830. It is not, however, to this factor that Mr. Clapham attributes the very rapid recovery of France after Waterloo, as compared with the slow recovery of Great Britain. The main factor responsible was that life in France was much more largely agricultural than it was here. In 1815 only about 10 per cent. of her inhabitants lived in towns of 10,000 inhabitants or more, and agriculture readily absorbed the demobilised peasants, whilst a couple of good harvests placed the country in a condition of prosperity. Germany and the rest of Europe had suffered more than France, but were still more predominantly rural in character. Hence the Continent generally had the elasticity of rather primitive economic conditions and recovered much more rapidly than did Great Britain, which was even then a great manufacturing country. Our goods could not, however, be bought by foreign countries as the protective duties then in vogue made it impossible for payment to be taken in produce. America, Mr. Clapham suggests, is in much the same position now as Great Britain was in 1817, and may, he thinks, suffer in the same way. On the other hand, Serbia, being an agricultural country, will, he holds, recover very rapidly in spite of the intensity of her sufferings and the greatness of her losses during the war.

Cadmium-Vapour Arc Lamps.

Cadmium-vapour arcs have proved very convenient for spectroscopic work, and especially for polarimeter work. The cadmium-arc spectrum is distinguished by five well characterised lines, distributed over the spectrum, and of these the red line is particularly useful, because it stands well out from the other lines in that region of the spectrum. Among the cadmium lamps described of late years are those of F. Bates, of T. M. Lowry and of H. Sand. Dr. H. J. S. Sand, of the Sir John Cass Institute, E.C., succeeded in greatly simplifying these lamps; but so far as we are aware, cadmium-vapour arcs are not yet on the market. According to an article, published by Frederick Bates, of the United States Bureau of Standards, in the *Philosophical Magazine* of March last, the difficulty is that the cadmium sealed in the quartz tube tends to crack the tube, or at least to peel off. Sand's lamp has the shape of an inverted U. The limbs are produced in capillaries through which the leads (of tungsten wire, in Bates' lamps) are introduced, being sealed in with lead. To fill the limbs with plugs of cadmium, the curved portion of the U is provided with a tubular projection opening out into a lateral chamber into which the cadmium is introduced. The cadmium is distilled into the evacuated U, the condensed metal flowing through a stricture into the tube, which acts as a filter. The inner walls of the quartz tube, in which the cadmium is to solidify, are lined with a little powdered zirconia to prevent adhesion between the cadmium and the quartz. This precaution, Bates states, does not prevent cracking of the tube on repeated use, and the filtering is inadequate to purify the metal. Bates tried to replace the cadmium by its amalgam; but the mercury lines then obscured the cadmium lines. He hence looked for another metal which would reduce the surface tension of the cadmium, and he found such a metal in gallium. When he mixed the cadmium with 3 per cent. of gallium and distilled the alloy in a vacuum of 0·001 mm. of mercury he obtained a lamp which worked very well on 100-volt circuits, taking 7 amperes at 14 volts. The faint gallium lines do not mask the cadmium lines, especially not the red line λ 6,439 A.U. Unfortunately Bates does not say where one can obtain gallium, which very few chemists have ever seen. There are no gallium minerals in the ordinary sense; the exceedingly rare metal occurs in a few minerals in very small proportions, and it adheres to the zinc, iron or aluminium with which it is associated. Gallium seems suited for the purpose indicated because it has a low melting-point, at 30·8 deg. C., and a high boiling-point above 1,500 deg. C. Provided no accidents occur, the cadmium and gallium may, of course, serve for indefinite periods in their quartz tube. But as gallium is so very rare, it is satisfactory to learn from Sand's reply (in the June issue of the same journal) that his properly-filled lamps will not crack. He is able to quote the independent testimonies of two users of his lamp, one of whom had heated the lamp at least 500 times for a total period of 600 hours, within three years, while the other had worked a Sand lamp continuously since 1916.

LITERATURE.

Modern Illuminants and Illuminating Engineering. By Leon Gaster and J. S. Dow. Second edition revised. London: Sir Isaac Pitman and Sons, Limited. [Price 21*s.* net.]

This is the second edition of a work that appeared some years ago when improvements in the methods of artificial lighting rapidly succeeded each other and men sought elegant and healthful means of illumination. That edition having been exhausted, a new one is necessary, but the authors have not thought the time convenient for the issue of a complete revision, that should incorporate whatever new devices and methods have been suggested during the war. Such exhaustive revision is deferred till the time when fresh enterprise and eager invention shall have multiplied appliances on a scale that will render their description compulsory. Such a course may be commercially prudent, but it may be doubted if it is dictated in the best interests of science. To produce light from artificial sources in quantity sufficient and by means economical is not enough: it is desirable to utilise the light so produced in the most judicious manner without waste and without excess, and to effect such a distribution among all who use light demands, that every assistance should be given to those who are engaged in the supply of artificial illuminants. To suppress obsolete matter is well, but if the authors are withholding information "owing to the present limitations as regards paper and printing," they are doing an injustice to themselves and to the public.

In a country having a considerable northern latitude, where in winter the opportunities for work would be sadly curtailed and the facilities for social intercourse diminished, adequate illumination is of the last importance for the well-being of the whole community and everyone is directly concerned in

promoting its efficiency, but for long, the inconveniences of darkness or semi-darkness seem to have been tacitly accepted as a necessary evil. Improvements were slow in coming and the theatres and ball rooms of our grandmothers, though described by old novelists as of dazzling brilliancy, must have been gloomy and depressing places. It is only within the last few decades that any serious attempt has been made to treat illumination as an art and science, capable of increasing light and comfort. Still more recent has been the recognition that a properly devised lighting apparatus is of hygienic importance. The authors undertake to explain the steps by which these happier results have been achieved and the work is long, for many have contributed in various ways. The physicist has introduced methods of accurate photometry and insisted on the adoption of sound theoretical principles in the distribution of illumination, he, too, has pointed out the considerations that should guide the appropriate choice of shades and reflectors, in order that artificial light should be made to approach as nearly as possible to ordinary light. The oculist has drawn attention to the possibility of insufficient, or improperly arranged, light, inducing impaired vision with all the evils it entails in defective education and incomplete equipment for the battle of life. The sanitarian urges the necessity of light as one of the means of destroying pathogenic bacteria and ensuring cleanliness. The co-operation of the artist and the architect is desirable to secure a pleasant and effective lighting of buildings, indeed every one, whatever his vocation may be, is interested in illumination, for all have to use light.

The early chapters are devoted mainly to the production of light, whether from gas, electricity, oil, petrol air gas, or acetylene. Of course the subject is far larger than can be dealt with adequately in the space allotted, but every page has some footnotes referring to original sources of information in English and foreign periodical literature. These footnotes are not the least valuable part of the treatise, for contributions have been made to a great variety of journals and the authors' long connection with *The Illuminating Engineer* has given them access to, and made them acquainted with, many unfrequent sources, generally unattainable. Still some references are apt to be a little behindhand in date, even 1914 seems a long way back now, and some date that would permit a judgment to be formed of the progress that has been made in some directions such as that of substituting a calorific for an illuminating test, would be welcome. The illuminating power of coal gas in many towns is now very low, and we are left without any assurance that the insistance on the calorific test is a sufficient remedy. It is possible that the co-operation of mantle manufacturers and gas companies might result in the adoption of a still higher calorific value at a lower cost of manufacture, but no information is vouchsafed concerning any progress made in this direction.

Two chapters on the mechanism of the eye and on colour, form a necessary sequence to those on the production of light, for it is through the eye that all our impressions of illumination are received. And it is to be feared that more attention has been paid to the production of a brilliant light, with due regard to economy of energy consumption, than to the physiological effect of such brilliancy on the apparatus of the eye itself. The cry of the public has been for more light, when suffering from some inconvenience that could not be properly located, when what was really needed was the proper distribution of the light already available. We have passed from the days when a difficulty was experienced in providing a sufficiency of illumination to another equally vital point, the avoidance of excess of light. Such a commonplace belongs to the alphabet of illuminating engineering, but we are not the less grateful to the authors for insisting on its due importance in promoting comfort, health, and efficiency of labour. The whole question of contrast, whether simultaneous or successive, and the power of the eye to adapt itself to startling changes of brilliancy, is one in which the public needs to be warned and instructed. The problems may be summed up in the word "glare," often regarded as an evil inseparable from artificial lighting, but one that can easily be prevented, usually by increasing the size of the source of light. The purpose of an enclosing globe is not simply ornamental, but to provide for this necessary enlargement with the view of getting the light on the object and not on the eye, a principle so obvious and elementary that one should be ashamed to insist upon it. The authors, however, guided by a wider experience, are no doubt justified in urging the adoption of methods of lighting in which glare is avoided by preventing the rays from the intensely bright surface of the illuminant falling directly on the eye. Perhaps an appeal to the æsthetic sense will prove more effectual than an argument addressed to physiological knowledge. A consequence of glare and of hard contrasts is to give disagreeably sharp dense shadows, against which the artistic soul revolts. Shadows there must be, to show up the features of cornices and columns, but the edges of these shadows should be soft and indistinct. Art controls illumination equally with science; and this becomes more evident when colour is introduced to enhance the effects of decoration. The authors grow enthusiastic over the charming results producible by means of the mercury vapour lamp that can be made to yield green, yellow, or blue monochromatic light, the neon tube producing vivid orange scarlet rays, and the Moore tube and flame carbon arc lamps, capable of giving various colours according to their constituents; but at present such combinations are the luxury of the rich and the envy of the masses.

An important chapter is that devoted to photometers and methods of measurement of light and of illumination. The measurement of the intensity of light by means of suitable photometers is not a difficult business when extreme accuracy is not needed, but the adjustment and calibration demands both skill and patience. The selenium cell does not seem to be an appropriate form, but the writer of this note must admit that he has no practical acquaintance with its use as recommended for the recording of daylight variation in schoolrooms, and if reserved for the determination of the fluctuations of light during an eclipse, the opportunities for its use in any one locality must be extremely limited. Sir William Preece touched the real difficulty in the application of photometry when he pointed out that the object sought was not the determination of the intensity of the lamp used but the actual intensity of illumination "on the surface of the book we are reading or of the paper on which we are writing." In this sense the measurement of the actual illumination is of quite a different type to that of ordinary photometry, and the difficulties become so great that ingenuity is taxed to its utmost to secure accuracy and to eliminate systematic errors. The authors explain and give examples for the derivation of "polar curves," and in this edition, Rousseau's graphical construction for determining the mean spherical candle-power and total flux of light is given and illustrated. Ulbricht's globe photometer is also illustrated and referred to apparently with approval, but the device seems inconveniently bulky and similar accuracy can be attained by simpler means.

In the next three chapters the devices are described that have been designed with the view of increasing the effectiveness of lighting, both in the house and in the street. The subject of globes and reflectors is very fully treated. With regard to some of these contrivances for increasing uniformity an objection has been raised that the advantages claimed are not warranted by reason of the loss of light due to absorption by the material of the globe. But this loss has probably been exaggerated. There is, of course, the possibility that the physical condition of the source is effected by enclosure, and the amount of light emitted diminished. Otherwise, it is difficult to explain the loss that has been reported as due to the action of a clear glass globe, a loss, occasionally quoted as high as 30 per cent., while in opaline globes the absorption is put as high as 68 per cent. On the other hand, a case is quoted in which the candle-power of a mantle was actually increased when surrounded by a clear glass globe. From the figures quoted, it would seem that there should be no practical difficulty in procuring a globe of good diffusing power, that would not absorb more than 20 per cent. Street lighting offers a large field for the judicious use of globes and reflectors in increasing the uniformity of illumination and the elimination of the disturbing effects of "glare." In interior lighting, the possibilities of indirect and semi-direct lighting are by no means exhausted. The excellent illustrations give some idea of what has been effected and encourage the hope that such a method of scientific distribution will be more generally adopted.

In the last two chapters are considered the plan of street lighting adopted in war-time and the employment of search lights, with other means of light projection involving the use of lenses and reflectors. With regard to the former, it is pointed out that the consequences of errors and the results of experience showed that protection would be best ensured by producing a substantially uniform illumination that avoided excessive and abrupt contrasts in brilliancy. Glare from comparatively brilliant lamps within the range of vision distracted drivers and pedestrians, causing accidents that might otherwise be avoided. There came a time, however, when a restriction of light was counselled as much with the view of diminishing the consumption of gas and electricity as of withholding information from enemy aircraft. But probably other motives than economy prompted this decision, for analysis shows that the gain from economy disappears, when weighed against compensating disadvantages. It is of more importance to note that the effort to secure greater uniformity in lighting thoroughfares in war time, a practice quite in harmony with the view generally urged before the war, might usefully be applied in times of peace.

The projection of light, or the prevention of the equal spread of radiant energy in all directions, cannot be adequately treated in the space allotted. It is only necessary to recall the many problems connected with lighthouse illumination, searchlights, warning lights on ships and moving vehicles cinema and theatrical exhibitions to show how varied are its uses and how complex the arrangements. We are afraid the principle is not seldom misused as seen in the brilliant beam emitted from the headlight of a motor car on a dark country road, to the danger of the driver of other vehicles, whose eye is accommodated to relatively dark surroundings. The authors' remedy for the inconvenience frequently experienced is to provide a screen, or suitable lens arrangement, that would limit the beam below a certain level and ensure the light being concentrated on the road where it is wanted, and not deflected into the eyes of approaching persons. In America, the candle-power of a pair of headlights measured on a level surface 200 ft. ahead of the vehicle must not be less than 1,200 c.p. and at 100 ft. distance at a height of 60 in. above the roadway must not exceed 2,400 c.p. In view of the high brilliancy now attainable some legal restriction appears to be desirable as a protection to the public, while giving due assistance to motor traffic.

If we consider the large portion of our time necessarily spent in artificial light, we shall understand how important is the subject and how vast the area the authors have sought to cover. Compression and omission have had to be ruthlessly practised and their task has been a difficult one. They have produced a book as interesting as it is practical and it should be the means of bringing greater comfort into our homes, improved hygiene in our workshops, enhanced enjoyment in places of entertainment, increased safety on our roads and more economical methods throughout a huge industry.

Robison's Manual of Radio Telegraphy and Telephony for the Use of Naval Electricians. By Captain S. S. Robison. Revised by Captain D. W. Todd and Commander S. C. Hooper of the United States Navy. Fifth revised edition. Annapolis, M.D.: The United States Naval Institute. [Price 1 dol. 50 cents.]

This book may be conveniently considered as consisting of two separate parts, the first imparting some elementary facts connected with electricity and magnetism, the second detailing the instructions issued to the radio-telegraphic operators in the United States Navy regarding the setting up and manipulation of their instruments. Since these are continually improving, with consequent enlargement of the field of operations, frequent revisions

are necessary to keep the directions up to date, and this is the fifth edition that has been published since 1907. Some advantage would follow the separation of the practical instructions, which require constant revision, from the discussion of the principles that do not alter, while these latter might be better adapted to the needs of a particular class. Of course, the object may be not so much to instruct as to get the work done in a uniform and efficient manner, and this view is the more probable, as there is little reasoned deduction throughout, the information being conveyed in a brief, precise form, as an officer might give orders to inferiors.

Notwithstanding five revisions, this information is not always so exact or complete as it might be, nor are all the obscurities adequately met. The first difficulty that a wireless operator is likely to encounter is the unexpected fact that optical waves of great length do not travel in straight lines, but are capable of curving round the surface of the earth. The explanation offered is not very intelligible, but certainly does not take the form one would have expected, for there is no mention of the solar and other influences ionising the gases in the upper regions of the atmosphere, whereby a conducting screen is formed, that deflects the waves before they can enter far into it and suffer any considerable absorption. Another difficulty which the student might well expect to have removed from his path occurs in the use of electro-static and electro-magnetic units, and the possible confusion that might arise from the double system. He will be disappointed; the revisers assert, with absolute truth, that "The entire system of units in electrical measurement is a monument to the ingenuity of scientists, but productive of many difficulties to students; careful study is, therefore, necessary." This exhibits the order of an officer rather than the function of the teacher. In any case, little assistance is vouchsafed to the tyro. Similarly, in practical work, details for the execution are given with minuteness, but explanation of processes is curtailed. For example, in the description of transmitting apparatus, doubtless if the direct current supplied by the shipboard dynamo plant is treated in the way directed by connecting with a motor generator and step-up transformers, a suitable high-frequency circuit with high voltage will result, but it may be doubted whether the operator will understand what he is doing, or, if brought into contact with different arrangements, would be capable of obtaining a desired result, more especially, as on shipboard, economy of space and instability of the steamer demand particular arrangements, and the exclusion of apparatus which can be conveniently used on shore. As an instance, Leyden jars are unsuitable owing to liability of fracture, and mica condensers are recommended. Also the use of oil in condensers is objectionable, owing to leakage. In the same way practical considerations limit the wave length that can be efficiently used on board ship, and also decide the power that can be employed with safety. The modifications of method and the necessity for adopting special mechanical devices due to the peculiar conditions obtaining on shipboard are very thoroughly explained, and will be appreciated by those who have been trained in the conditions that ordinarily prevail in the laboratory. A navy portable set, contained in a suit case, and weighing about 75 lb complete, strikes one as a very natty arrangement. One half the case accommodates the condenser, inductance and key, the other the motor generator, quenched gap, transformer and receiving apparatus, with arrangements for connecting up with a lighting or power circuit.

The erection of aerials and antennæ seem scarcely to come within the range of the naval electrician, but some forms are figured and described. One design used in submarines, consisting of an earthed loop attached to the submarine, is of particular interest. This loop takes the form of a single highly-insulated wire attached at the ends to the metal hull of the submarine, the primary of the radiating circuit being connected in series with the respective ends of the so-called aerial by means of two down leads through watertight insulators in the hull. This type, which can be used either for sending or receiving, is held to be highly efficient, and since it is unnecessary to unship the earthed loop when the submarine submerges, communication can be maintained with a shore station though the top of the aerial is 20 ft. below the surface. So small an outfit as a 5-kilowatt set, using a wave length of 950 m. at 100 miles distant, was able to transmit to a submarine when the loop was 8 ft. below the surface. The loop is very directional and transmission is still possible when the loop is partially submerged. No doubt this form of submarine aerial was largely used during the war, and many improvements have been effected which have not yet been published. Another form of antennæ which was much used by all the belligerents consists of highly-insulated wires buried sufficiently deep below the earth's surface to be in contact with underground water. Many advantages are claimed for this design, principally on account of cheapness of construction, no towers being required, and no losses from winds and storms. Signals are said to be received with an intensity equal to that of overhead wires, and there is less interruption from "strays." The system is exceedingly directional, and it is not necessary to earth receiving apparatus for protection from lightning. A suitable form consists of two wires run in a direction pointing towards the station from which signals are to be received. The outer ends of the wire are insulated, and the inner ends of the wire lead to the primary of the ordinary receiver. Owing to the extreme high capacity of these wires, a condenser is inserted in series with one, so that the system may be tuned to the incoming wave length of the received signal.

The radio compass, an instrument as ingenious as it is useful, further illustrates the application of wireless telegraphy to the purposes of navigation. The general theory and construction of this device are described very completely, though doubtless many improvements in detail were introduced in the last years of the war, to which it is not prudent to refer. But the method of determining the direction from a station by a single message, and of the absolute position of the steamer by the combination of information received at two or more stations, is fully explained, and will be found very interesting. The method by which a possible error of 180 deg. in the bearing is eliminated is specially deserving of attention. Radio compass stations are established off the coast of the United States from New York to Charlestown, but the Canadian stations are not mentioned. Their methods of working may be different from the American plan, which arranges for all the messages received at subsidiary stations to be forwarded to one central plotting station. When a vessel calls for a bearing, the receiving compass stations each take the bearing and telegraph it directly to the central office, where the bearings are plotted on a chart, and the resultant position is transmitted by radio to the vessel. The time consumed for the whole operation is about five minutes. In the cases we have seen in this country, when a vessel wants to know its position, the bearing is transmitted from each station that receives the signal and the plotting, a very simple matter, is effected on board ship. When the stations are well conditioned with regard to the ship, the accuracy is most satisfactory. The revisers state that the radio compass may be read by an expert operator with no greater error than 1 deg. in the bearing, and that, when the steamer is close to the coast, the position forwarded will be within a mile, and will not be more than four or five miles in error if the vessel is distant as much as 200 miles.

The special modifications of apparatus to be used on seaplanes and in aircraft equipment generally are adequately described, but the necessary changes are slight. The metal parts of the fuselage serve as a substitute for "earthing." Considering the necessity for reducing weight and the limited space for working, it is satisfactory to note that the apparatus on the larger class of aeroplane is capable of transmitting reliably 600 miles, though, except on the Cairo-to-Cape Expedition, it is difficult to conceive a situation in which it is necessary to send a message so great a distance. In the more modern aircraft the transmitters are of the valve type, using a generator directly connected to the engine, but a storage battery is supplied to be used on emergency. The receivers use the audion detector, but, notwithstanding all precautions for deadening sound, receiving is very difficult. The antennæ is of the weighted trailing type, removable at pleasure. The weight of the outfit for short range is roughly 50 lb., while a long-range set may amount to 150 lb., according to the power of the transmitter.

The final chapters contain valuable information on the methods of installation, adjustment and measurement. Calibration and tuning are considered very practically, and the remarks on the care of instruments and methods of operation may be read with advantage by all who are actively engaged in radio-telegraphy and telephony. The Extracts from Laws and Regulations, of course, apply only to the U.S. Naval Communication Service, but these instructions may be usefully compared with those issued by our own authorities. As a general rule, it appears that the Naval Communication Service is better equipped and more prepared to act in times of emergency as an adjunct to the Telegraph Service than is the case in this country. But over our very limited area the wires may be so closely packed that interruptions are less acute, and can be adequately met without assistance from outside the regular Service.

BOOKS RECEIVED.

Canada Department of Mines. Graphite. By Hugh S. Spence, M.E. Ottawa: Thomas Mulvey.

Malay Self-Taught, By the Natural Method, with Phonetic Pronunciation. By Abdul Majed. London: E. Marlborough and Co. [Price 3*s.* net.]

The Motor Manual. Twenty-third edition. London: Temple Press, Limited. [Price 3*s.* 6*d.* net.]

The Theory of Electric Cables and Networks. By Alexander Russell, M.A., D.Sc. Second edition. London: Constable and Co., Limited. [Price 24*s.* net.]

Manufacture and Uses of Alloy Steels. By Henry D. Hibbard. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Limited. [Price 7*s.* 6*d.* net.]

United States Department of Commerce, Bureau of Foreign and Domestic Commerce, Monthly Summary of Foreign Commerce of the United States. March, 1920. Washington: Government Printing Office. [Price 10 cents.]

LABOUR TROUBLE: ITS IMMEDIATE CAUSE AND REMEDY.

To the Editor of Engineering.

Sir,—In criticising my suggestion that employers of labour should recognise trade unions to the extent of bargaining with them for the supply of all the labour required in their workshops, and refuse to treat with any employee individually, Mr. William Collison, general secretary of the National Free Labour Association, asks, "Is 'An Employer' ignorant of the fact that at least two-thirds of the wage earners of the country are either non-unionists or trade unionists by compulsion?"

In reply, I would say that I thought it just as unnecessary for me to explain that I only had in mind the experiment being made in the case of a highly unionised industry, as I think it unnecessary to ask Mr. Collison to admit that his general estimate does not apply to all industries individually, but that there are some more highly unionised than others.

But even if his estimate be applicable to the most highly unionised industry, surely it strengthens rather than weakens my case. For if, on the one hand, there is already such a large proportion of labour opposed to the tyranny of the unions, we ought to expect the speedy overwhelming of the unions by the dissentients as soon as we add to the existing friction that which must inevitably arise from the taking over by the union of the invidious task of employment, maintenance, and dismissal; whereas, on the other hand, should the union succeed in overcoming all difficulties, the present non-unionists and unwilling trade unionists would at least stand to benefit by the payment of a permanent subsistence wage whether in or out of employment.

Finally, no one will disagree with Mr. Collison in his objection to the element of compulsory membership of a trade union involved in my proposal; but what he does not seem to appreciate is the fact that we all—employers, non-unionists, unwilling unionists, and general public alike—are already subject to a worse tyranny, for which an alternative solution of calculable lasting effect has yet to be put forward.

Yours faithfully,

"An Employer."

The Institution of Mining Engineers.—The thirty-first annual general meeting of this Institution will be held in the Lord Mayor's Parlour, Town Hall, Manchester, on Wednesday, September 15, at 10.30 a.m. and 2.30 p.m., when a number of papers will be read and discussed. Excursions and visits have been provided for on the following days. Further particulars may be obtained from the Secretary, 36, Victoria-street, Westminster, S.W. 1.

A WORKSHOP SHERARDIZING UNIT.

The claims of Sherardizing as a protective process are too well established to need discussing, but, while this is so, the system is not applied as widely as it might be, in view of the ease of working it. It is well known that it gets over the difficulties of working a large bath of molten metal, which, for the sake of economy, must be operated on an extensive scale. Small batches of articles cannot well be galvanised in works below moderate size, because of the trouble and cost of operating such a plant intermittently, resulting in work having to be sent away to be done, with all the attendant risks, especially in these days, of delay in transit. The latter trouble has been one of the causes for Sherardizing not having become so popular as it might otherwise have been by now, the works in this country which laid down furnaces for working the process having been comparatively few, so that delays and other difficulties have often arisen in getting work of this class done.

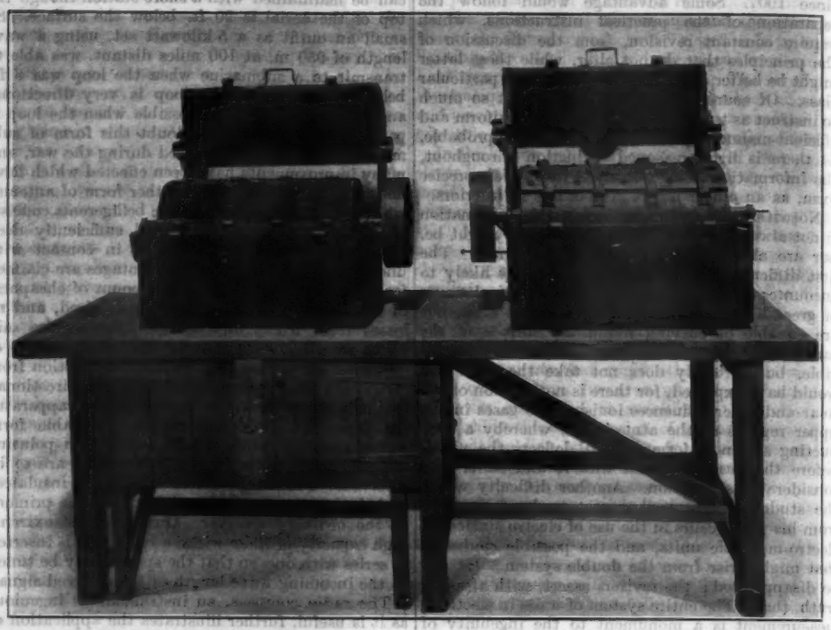
In order to bring the process in convenient form within the capacity and capabilities of small works, Messrs. Metal Industries, Limited, of Sunbury-on Thames, have recently brought out a type of plant which involves no expensive brickwork fixtures. Strictly speaking, the plant is not absolutely self-contained, since it requires either electric power, or gas and belt power, from outside sources, but the furnace itself requires no installation as, in all the smaller sizes, it can be mounted on a bench which can be placed in any convenient position in a workshop. The smallest furnaces are heated electrically, and electricity can, of course, be employed for rotating the drums. In the size shown the drums are rotated by belt from the shop-shafting; the furnace is heated by gas, this being the only connection to be made at the time of installation.

In our illustration, the furnace unit is shown open to the right. The articles are packed loosely, with the zinc dust, in the drum seen inside the case, and the drum closed by a cover door, which is wedged down to prevent leakage of the dust during rotation. The drum is supported on two bearings, outside one of which is the driving pulley. The journal and shaft at the other end are hollow for the purpose of receiving a thermometer for gauging and maintaining the correct temperature inside the drum. The drum and the furnace casing are of sheet iron. The casing is completely lined with refractory material and the upper part is hinged and capable of being thrown back. A chimney hole is provided and connection can be made by means of a telescopic joint with a permanent up-take overhead. A series of several rows of gas jets distributes the heat evenly over the length of the revolving drum underneath. After treatment in the zinc dust, which vaporises in contact with the iron or steel, the drum is lifted out and transferred to the left-hand casing. This is virtually a rumbler. The sheet iron door is removed from the drum, and its place taken by a wire gauze screen of about ¼-in. mesh. The rumbler casing has a hopper bottom and when the drum is in position and the top closed, as the drum is revolved, again by belt drive, the excess of zinc dust escapes into the hopper below. This process effectually removes the dust from the interior of hollow articles or from intricate exteriors. Immediately below the rumbler is a drawer or cupboard. In this drawer is another drum placed on blocks directly below the hopper spout. This drum, therefore, catches all the zinc dust discharged from the drum in the rumbler above, and is ready for a new batch of articles after the addition of a small amount of make-up zinc dust. It will be observed that every means is taken to minimise loss both of heat in the furnace, and of zinc dust. If three drums are employed, the three stages of the process can be run simultaneously.

The installation will be seen at once to offer many advantages to the small user. The process results in no stand-by losses except overhead charges due to the comparatively small initial cost. It can be operated at any time with a minimum of preparation, and can be successfully worked by unskilled labour; all that is necessary is to light the burner and keep the thermometer at the desired figure. Units of this type could be installed in numerous very small shops with good results. They could be operated satisfactorily on intermittent work such as batches of screws, bolts, &c., for motor-car repairs, even on a small scale, and many other uses will at once suggest themselves where, in addition to handiness of working, the Sherardizing process offers peculiar advantages over galvanising.

It is known that this process lends itself extremely well to art-metal work, and here small units are likely to prove most welcome. The delightfully beautiful and varied effects obtainable with Sherardising will be placed within the capabilities of the small craftsman. This seems a direction in which the process might be developed with extremely pleasing results, possibly, as skill increases, in conjunction with chasing or other arts, and we may confidently look for a considerable impetus being given to it as an artistic craft now that Sherardizing units of the size and ease of manipulation, we have described above, are available.

A WORKSHOP SHERARDIZING UNIT.



BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

*Address to the Engineering Section.**

By Prof. C. F. Jenkin, C.B.E., M.A., President of Section.

The importance of research in all branches of industry is now becoming fully recognised. It is hardly necessary to point out the great possibilities of the Board of Scientific and Industrial Research, formed just before the war, or to lay stress on the attention which has been called to the need for research by events during the war. Probably in no branch of the Services was more research work done than in the Air Service, and the advances made in all directions in connection with flying were astonishing. My own work was confined to problems connected with materials of construction, and as a result of that work I have come to the conclusion that the time has come when the fundamental data on which the engineering theories of the strength and suitability of materials are based require thorough overhauling and revision. I believe that the present is a favourable time for this work, but I think that attention needs to be drawn to it, lest research work is all diverted to the problems which attract more attention, owing to their being in the forefront of the advancing engineering knowledge, and lest the necessary drudgery is shirked in favour of the more exciting new discoveries.

It has been very remarkable how again and again in aeroplane engineering the problems to be solved have raised fundamental questions in the strength and properties of materials which had never been adequately solved. Some of these questions related to what may be termed theory, and some related to the physical properties of materials. I propose to-day to describe some of these problems, and to suggest the direction in which revision and extension of our fundamental theories and data are required and the lines on which research should be undertaken. Let us consider first one of the oldest materials of construction—timber. Timber was of prime importance in aircraft construction. The first peculiarity of this material which strikes us is that it is anisotropic. Its grain may be used to locate three principal axes—along the grain, radially across the grain and tangentially across the grain. It is curious that there do not appear to be generally recognised terms for these three fundamental directions. A very few tests are sufficient to show that its strength is enormously greater along the grain than across it. How, then, is an engineer to calculate the strength of a wooden member? There is no theory, in a form available for the engineer, by which the strength of members made of an anisotropic material can be calculated.

I fancy I may be told that such a theory is not required—that experience shows that the ordinary theory is quite near enough. How utterly misleading such a statement is I will try to show by a few examples. Suppose a wooden tie or strut is cut from the tree obliquely so that the grain does not lie parallel to its length. In practice it is never possible to ensure that the grain is accurately parallel to the length of the member, and often the deviation is considerable. How much is the member weakened? This comparatively simple problem has been of immense importance in aeroplane construction, and, thanks to the researches made during the war, can be answered. The solution has thrown a flood of light on many failures which before were obscure. If the tensile strengths of a piece of timber are, say, 18,000 lb. per square inch along the grain and 800 lb. per square inch across it (radially or tangentially) and the shear strength is 900 lb. per square inch along the grain—these figures correspond roughly with the strengths of silver spruce—then if a tensile stress be applied at any angle to the grain the components of that stress in the principal directions must not exceed the above strengths, or failure will occur. Thus we can draw curves limiting the stress at any angle to the grain, and similar curves may be drawn for compression stresses. These theoretical curves have been checked experimentally, and the results of the tests confirm them closely, except in one particular. The strengths at small inclination to the grain fall even faster than the theoretical curves would lead us to expect. The very rapid drop in strength for quite small deviations is most striking.

Similar curves have been prepared for tensile and compressive stresses inclined in each of the three principal planes for spruce, ash, walnut and mahogany, so that the strengths of these timbers to resist forces in any direction can now be estimated reasonably accurately.

As a second example consider the strength of plywood. Plywood is the name given to wood built up of several thicknesses glued together with the grain in alternate thicknesses running along and across the plank. The result of this crossing of the grain is that the plywood has roughly equal strength along and across the plank. Plywood is generally built up of thin veneers, which are cut from the log by slicing them off as the log revolves in a lathe. Owing to the taper in the tree trunk and to other irregularities in form, the grain in the veneer rarely runs parallel to the surface, but generally runs through the sheet at a more or less oblique angle. As a consequence the strength of plywood is very variable, and tests show that it is not possible to rely on its having more than half the strength it would have if the grain in the veneers were not oblique. It is therefore obviously possible to improve the manufacture enormously by using veneers *split off*, following the grain, in place of the present sliced veneers. The superiority of split or riven wood over cut wood has been recognised for ages. I believe all ladders and ladder rungs are riven. Hurdles, hoops and laths are other examples. Knees in ships are chosen so that the grain follows the required outline.

Owing to the enormous difference in strength in timber along and across the grain, it is obviously important to get the grain in exactly the right direction to bear the loads it has to carry. The most perfect example I ever saw of building up a plywood structure to support all the loads on it was the frame of the German Schutte-Lanz airship, which was made entirely of wood. At the complex junctions of the various girders and ties the wood, which was built up of very thin veneers—hardly thicker than plane shavings—layers were put on most ingeniously in the direction of every stress. During the war I rejected numerous types of built-up struts intended for aeroplanes, because the grain of the wood was in the wrong direction to bear the load. An example shown—a McGruer strut—is one of the most elegant designs, using the grain correctly.

Many of the tests applied to timber are wrong in

* Address delivered to Section G of the British Association at Cardiff on Tuesday, August 24, 1920.

theory and consequently misleading. For example, the common method of determining Young's modulus for timber is to measure the elastic deflection of a beam loaded in the middle and to calculate the modulus by the ordinary theory, neglecting the deflection due to shear, which is legitimate in isotropic materials; but in timber the shear modulus is very small—for example, in spruce it is only about one-sixtieth of Young's modulus—and consequently the shear deflection becomes quite appreciable, and the results obtained on test pieces of the common proportions lead to errors in the calculated Young's modulus of about 10 per cent.

Lantern views* shown illustrate three standard tests; the first is supposed to give the shearing strength of the timber, but these test pieces fail by tension across the grain—not by shearing. Professor Robertson has shown that the true shear strength of spruce is about three times as great as the textbook figures, and has designed a test which gives fairly reliable results. The second figure represents a test intended to give the mean strength across the grain, but the concentration of stress at the grooves is so great that such test pieces fail under less than half the proper load. This fact was shown in a striking manner by narrowing a sample of this shape to half its width, when it actually bore a greater total load—*i.e.*, more than double the stress borne by the original sample. The third figure represents a test piece intended to measure the rather vague quality, "strength to resist splitting." The results actually depend on the tensile strength across the grain, on the elastic constants, and on the accidental position of the bottom of the groove relatively to the spring or autumn wood in the annular rings. Unless the theory is understood, rational tests cannot be devised.

There are some valuable tropical timbers whose structure is far more complex than that of our ordinary northern woods. The grain in these timbers grows in alternating spirals—an arrangement which at first sight is almost incredible. The most striking example of this type of wood I have seen is the Indian "Poon." The sample on the table has been split in a series of tangential planes at varying distances from the centre of the tree, and it will be seen that the grain at one depth is growing in a right-hand spiral round the trunk; a little farther out it grows straight up the trunk; further out again it grows in a left-hand spiral, and this is repeated again and again, with a pitch of about 2 in. The timber is strong and probably well adapted for use in large pieces—it somewhat resembles plywood—but it is doubtful whether it is safe in small pieces. No theory is yet available for estimating its strength, and very elaborate tests would be needed to determine its reliability in all positions. I had to reject it for aeroplanes during the war for want of accurate knowledge of its properties.

These examples show how necessary it is to have a theory for the strength of anisotropic materials before we can either understand the causes of their failure or make full use of their properties or even test them rationally.

The second material we shall consider is steel, and in dealing with it I do not wish to enter into any of the dozen or so burning questions which are so familiar to all metallurgists and engineers, but to call your attention to a few more fundamental questions. Steel is not strictly isotropic—but we may consider it to be so to-day. The first obvious question the engineer has to answer is, "What is its strength?" The usual tests give the ultimate strength, yield point, elastic limit, the elongation, the reduction of area, and perhaps the Brinell and Izod figures. On which of these figures is the dimension of an engine part, which is being designed, to be based? If we choose the ultimate strength we must divide it by a large factor of safety—a factor of ignorance. If we choose the yield point we must remember that none of the higher grade steels have any yield point, and the nominal yield point depends on the fancy of the tester. This entirely imaginary point cannot be used for accurate calculation except in a very few special cases. Can we base our calculation on the elongation—the reduction of area—the Izod test? If we face the question honestly we realise that there is no known connection between the test results and the stress we can safely call on the steel to bear. The only connecting link is that cloak for our ignorance—the factor of safety.

I feel confident that the only reliable property on which to base the strength of any engine part in the suitable *fatigue limit*. We have not yet reached the position of being able to specify this figure, but a considerable number of tests show that in a wide range of steels (though there are some unexplained exceptions) the fatigue limit for equal ± stresses is a little under half the ultimate strength, and is independent of the elastic limit and nominal yield point, so that the ultimate strength may be replaced as the most reliable guide to true strength, with a factor—no longer of ignorance, but to give the fatigue limit—of a little over two.

If the fatigue limit is accepted as the only sound basis for strength calculation for engine parts, and it is difficult to find any valid objection to it, then it is obvious that there is urgent need for extensive researches in fatigue, for the available data are most meagre. The work is laborious, for there is not one fatigue limit, but a continuous series, as the signs and magnitudes of the stresses change. Many problems in connection with fatigue are of great importance and need much fuller investigation than they have so far received—*e.g.*, the effect of speed of testing; the effect of rest and heat treatment in restoring fatigued material; the effect of previous testing at higher or lower stresses on the apparent fatigue limit of a test piece. Some observers have found indications that the material may possibly be strengthened by subjecting it to an alternating stress below its fatigue limit, so that the results of fatigue tests may depend on whether the limit is approached by increasing the stress or by decreasing it.

Improved methods of testing are also needed—particularly methods which will give the results quickly. Stromeyer's method of measuring the first rise of temperature, which indicates that the fatigue limit is passed, as the alternating load is gradually increased, is most promising; it certainly will not give the true fatigue limit in all cases, for it has been shown by Bairstow that with some ranges of stress a finite extension occurs at the beginning of a test and then ceases, under stresses lower than the fatigue limit. But the fatigue limit in that case would not be a safe guide, for finite changes of shape are not permissible in most machines, so that in that case also Stromeyer's test may be exactly what is wanted. It can probably be simplified in detail and made practicable for commercial use. Better methods of testing in torsion are also urgently needed, none of those at present used being free from serious defects. Finally, there is a fascinating field for physical research in investigating the internal mechanism of fatigue failure. Some most suggestive results have already been obtained, which extend the results obtained by Ewing.

For members of structures which are only subjected to steady loads I suggest that the safe stress might be defined by limiting the corresponding permanent set to a small amount—perhaps ½ per cent. or ¼ per cent. This principle has been tentatively adopted in some of the aircraft material specifications by specifying a proof load which must be sustained without a permanent extension of more than ½ per cent. Whether this principle is suitable for all materials and how it will answer in practice remains to be proved by experience. It is at any rate a possible rational basis for determining the useful strength of a material under steady loads.

The relation between the proof stress and the shape of the stress-strain diagram is shown in a lantern slide. The curve is the record of an actual test on a certain copper alloy. If a length A B corresponding to ½ per cent. elongation be set off along the base line and a line B P be drawn through the point B parallel to the elastic line, to cut the curve in P, then the stress at P is the stress which will give ½ per cent. permanent set. Though ½ per cent. may appear rather a large permanent set to allow, it will be seen from the figure that it is less than the elastic elongation would have been at the same stress, and we do not usually find elastic elongation serious. As a commercial test the proof load is very easily applied. For this alloy the specified proof load is shown by the horizontal line so labelled. This load is to be applied and released, and the permanent extension is required by the specification to be less than ½ per cent. This sample passes the test easily. On the figure the condition for complying with the specification is that the curve shall fall above Q. But the test does not require the curve to be determined.

If we admit that the fatigue limit is the proper basis for engine-strength calculations, there are a number of interesting modifications required in the common theory of the strength of materials. It will no longer be possible to neglect, as has been so general in the past, the uneven distribution of stress in irregularly shaped parts of machines. It has been generally recognised that sharp corners should be avoided when possible, but no theory is available to enable the stresses at corners to be calculated or to enable their effect on the strength of the member to be estimated. If fatigue is the critical factor in failure under fluctuating stresses such theory is most necessary. Even the roughest guide would be of great value. The nature and magnitude of the concentrations of stress which occur in practice have been investigated experimentally by Professor Coker by his elegant optical method which has given most valuable results, some of which are already being used in designing offices. If the mathematical theory is too difficult, it may be possible to lay down practical rules deduced from such experimental results—but the method still has many limitations, perhaps the most serious being that it can only be used on flat models. I believe Professor Coker expects to be able to extend the method to round models.

As a simple example to show the importance of the subject, let us consider the effect of a groove round a straight round bar subject to alternating tension and compression—such a groove as a screw thread. There will be a concentration of stress at the bottom of the groove. The ratio of the stress at the bottom of a groove to the mean stress in the bar has been worked out mathematically by Mr. A. A. Griffith, and his calculations have been confirmed experimentally by his elegant soap-bubble method. The ratio depends on the relation between the depth of the groove, the radius at the bottom, and slightly on the angle between the sides. For a Whitworth form of thread the ratio will be about 3. If the fatigue limit is exceeded at the bottom of the groove the metal will fail and a minute crack will form there; this crack will soon spread right across the bar and total failure will result. Thus we see that the safe mean stress in the bar will be reduced to one-third what a plain bar will bear. The truth of this theory regarding the importance of concentrations of stress has still to be proved experimentally; if true, it is of far-reaching importance, since it applies to all concentrations of stress in machine parts subject to fluctuating loads.

The theory does not apply to steadily loaded members; in these the local excess of stress is relieved by the stretching of the minute portion which is overloaded, and no further consequences follow.

The theory appears to apply to grooves however small, and has an important bearing on the smoothness of the finish of machine parts. The surface of any engine part finished by filing is certainly entirely covered with scratches. Emery likewise leaves the surface scratched—though the scratches are smaller. If, however, polishing be carried further the surface may ultimately be freed from scratches and left in a burnished condition. In this condition amorphous metal has been smeared over the surface—the smooth appearance is not simply due to the scratches being too small to see. The strength—under alternating stresses—appears to depend on the form of the scratches, and if the ratio of radius at the bottom of the scratch to its depth is fairly large, very little weakening occurs. It seems probable in the ordinary engineering finish produced by emery and oil that the scratches are broad and shallow. This subject is being investigated. A considerable amount of evidence has been collected from practical experience pointing to the important effect which a smooth finish has on the strength of heavily stressed engine parts.

Fatigue is probably the cause of failure of wires in wire ropes. A good deal of valuable experimental work has been done on the life of ropes, but so far as I am aware there is no satisfactory theory of their strength. This subject also requires research, and it seems probable that valuable practical results might follow if the true explanation of the cause of the breakages of the wires was determined.

These are only examples, but they may be sufficient to show how much work both experimental and theoretical requires to be done to give the engineer a really sound basis for the simplest strength calculations on any moving machinery. But there are more fundamental questions still which must be tackled before the simplest questions of all which meet the engineer can be answered scientifically. The two most urgent and most important questions which I met with during the war in connection with aircraft were always the same—Why did some part break? and, What is the best material to use for that part? It was most disconcerting to find how inadequate one's knowledge was to answer these two simple questions. The common answers are, to the first, "It broke because it was too weak; make it stronger"; and to the second, "General practice indicates such a material as the best—better not try any other or you may have trouble." In aircraft weight is paramount, and to make a part stronger—*i.e.*, heavier—had to be the last resort, and when used was almost a confession of failure. "General practice" was no guide in aeroplane engines, which are built of the strangest materials. The origins of fractures were traced to many causes, often lying far away from the site of the breakage; but with these I am not concerned to-day. I wish to confine our consideration to the actual fracture and to ask, "What stress caused the fracture?" and "What property of the metal was absent which would have enabled it to withstand that stress?" And again, "What other material possesses suitable properties to withstand the stresses better?" These are the fundamental questions which I have referred to—and which urgently need answers.

As an example I will take a broken propeller shaft. It has broken in a beautiful spiral fracture. What stress causes that? I have failed to explain it by any of the facts I know about the steel it is made of. It is, of course, a fatigue fracture—*i.e.*, it spread gradually. The questions to be answered are, Did it fail under tension, bending or torsion? and, Why was a spiral direction followed by the failure as it spread?

It may be objected that the question is unimportant. I think not. For example, till we can determine the nature of the stress we cannot indicate the nature of the load—thus I cannot say if it broke under a torsional load (possibly torsional vibration) or under a bending load (possibly due to some periodic variation of thrust on one of the propeller blades as it passed an obstruction.) Until the nature of the load which caused the failure is known, it is very difficult to take steps to guard against similar accidents. For the most urgent reasons, therefore, we require to be able to understand the fracture, as in nearly all aircraft problems man's lives hang on the answer.

Turning now to the question of the most suitable material, I will take as an example the material for the crankshaft of an aeroplane engine. A few months before the Armistice there were difficulties in getting sufficient supplies of the high-grade nickel-chrome steel forgings then in general use for shafts, and proposals were made to use a plain carbon steel. Such a steel would be about 30 per cent. weaker, according to the ordinary tests. A conference of leading metallurgists and engineers was held to discuss the suggestion. No one present ventured to predict whether the weaker steel would answer or not, or whether the dimensions would have to be increased or not. It was pointed out that a French engine was now using 50-ton steel with better results than when using the 100-ton steel for which it was designed, no changes in dimensions having been made. Such a reduction of strength might be understood in ordinary engineering where there are large margins of safety, but in an aeroplane engine, in which every ounce of metal is cut off which can be spared, they show how completely ignorant engineers are of what the suitability of material depends on. As another example, Why are oxygen cylinders annealed—repeatedly? Annealing reduces the steel to its weakest condition. I believe the fondness for annealing is due to our ignorance of the properties we require. Perhaps the quality of steel which an engineer fears most is brittleness. He believes that annealing will soften it and reduce the brittleness; so he anneals, blindly. The fact is that we do not know what brittleness is—we cannot define it—we cannot measure it—though there are endless empirical tests to detect it. Till we know what it means and can measure it we are in a miserable position. During the war I was consulted on what could be done to reduce the enormous weight of oxygen cylinders, and I advised that experiments should be made on the high-quality alloyed steel tubes we were using in aircraft construction. The department dealing with these tubes

* We regret we cannot reproduce the lantern views.

took the matter up, and alloyed steel cylinders, properly heat-treated, were made. These were, I believe a success, and only weighed a small fraction of the old-fashioned cylinders. But my suggestion was little more than a guess, and no means were known of accurately testing the suitability of the material, so they were only accepted after passing any number of empirical test consisting of various kinds of rough usage, to see if they would crack or burst. Surely an engineer should be able to say whether a cylinder is safe without dropping it from the roof or rolling it down the front door steps to see if it breaks.

These examples refer only to different grades of the same material—steel—but how far worse off we are when the problem is whether some other alloy would be suitable to replace steel. Proposals have been made, for example, to replace the very hard steel used at present for connecting-rods by duralumin or some other forged aluminium alloy. It seems worth trying; but who, in our present state of ignorance of the real properties of metals, will say if the experiment will be a success?

How difficult it is to prophesy may be illustrated by the results of two empirical tests on duralumin and steel sheets of the same thickness. The ultimate strengths and elongations of the steel and the duralumin were roughly equal. The lantern slides show that under reverse-bend tests they both follow the same law, the steel being the better. But under the cupping test they follow opposite laws.

The suitability of different materials presumably depends on their fundamental physical properties. These may be many, but some physicists think that they are probably really very few, and that, knowing these few, it may be possible to deduce all the complex properties required by the engineer and to state with certainty how materials will behave under any conditions of service. This is the most fundamental problem which needs solution to enable the knowledge of the strength of materials to be put on a sound foundation. It will need the co-operation of able physicists, metallurgists and engineers to solve it.

While urging the importance of research in the fundamental theories of stress and fundamental properties of materials, I wish to lay special stress on the nature of the researches required. Engineers are intensely practical men, and their practice has generally been ahead of their theory. The difficulties they have met have been dealt with, often with the greatest ingenuity and skill, as special problems. They have seldom had time or opportunity to solve the general problems, and as a result thy are used to making their experiments and trials as close a copy—usually on a smaller scale—of the real thing as possible. The results obtained in this way, while they are applicable to the particular problem, are of little general use. They depend on many factors. The researches I am now advocating must be of a diametrically opposite description. They must be absolutely general, and the results must depend on one factor only at a time, so that general laws may be established which will be applicable to all special problems.

There are many other similar gaps in our knowledge to which I have not time to refer to-day. I have tried to show that we need most of all a real knowledge of the fundamental properties of materials, from which we shall be able to deduce their behaviour in any condition of service, so that we may be able to compare the relative merits of diverse materials for any particular purpose.

Secondly, that we need a practical method of calculating the stresses in parts of any form, so that concentrations of stress may be avoided or that their magnitudes may be known and allowed for.

Thirdly, that we need a rational connecting link between the tests made on materials and the stresses they will bear in service, to replace the factor of safety. I have suggested two tests, the proof load and the fatigue limit, which might be used directly in estimating the allowable working stresses.

Fourthly, that we need a mathematical theory for the strength of anisotropic materials, of which timber is an extreme and important example.

When the notes for this address were first drafted I ended by an appeal to the Board of Scientific and Industrial Research to undertake the necessary research work. Since then the Aeronautical Research Committee has been constituted, and a sub-committee has been appointed to deal with "Materials." I have great hopes that the committee will tackle many of these problems. I will therefore conclude by appealing to all who can help to assist that committee in their endeavour to solve these most important and fascinating, but most difficult, problems.

CUTTING EDGES.*

By Col. R. E. Crompton, C.B.

We are so familiar with the cutting appliances in common use, our razors, knives, shears, axes, wood-working tools and so on, that we are apt to consider that they have been so thoroughly developed during long course of time, by the inherited experience of the manufacturers and users, that it is unlikely that any material improvement either in their form, in the steel used for them or in the angle of the cutting edge can now be introduced.

No doubt this was true so long as the angle and shape of the cutting edge was controlled by the physical properties, i.e., the hardness and the strength to resist fracture of the only material which for many centuries has been available, i.e., iron combined with carbon, and which we have always called steel. When engineers designed machine tools in which the cutting edges are so supported that they can be forced into the material to be cut with pressures not possible to be used for hand tools, this same carbon steel was the only steel available. But when Mushet, succeeded by a long line of inventors, gave us the new series of modern steels generally known as high-speed, which will hereafter for brevity be called H.S. steels, and which contain, in addition to carbon, other metals—tungsten, cobalt, molybdenum, nickel, vanadium, and so on—engineers found themselves in possession of materials for their cutting edges which were far stronger to resist fracture than the carbon steels, and which could be made sufficiently hard to take the place of carbon steels. These steels can be subjected to greater heat, caused by the friction of cutting at high speed, than can be withstood by carbon steel points, on account of carbon steel losing its hardness and cutting qualities when raised to these temperatures.

Last year the Institution of Mechanical Engineers formed a Cutting Tools Research Committee to regularise research into this important matter. The author, who is a member of this committee, has now been for some time engaged on experimental investigations of the phenomena attending the working of cutting edges so far as these show the causes of the blunting of tools, and has come across some facts which appear likely to interest the general public as well as the engineers who use the modern steels for machine tools.

All cutting edges are developments of the wedge; two surfaces, A and B, meet at an angle, and are either forced by steady pressure or by a series of blows into the material to be cut, so as either to split or to pare a slice from the surface.

Cutting operations are of two kinds: in most cases where the cutting edge is supported in the machine tool, the cutting action is a purely splitting away of a part of the material operated on, but a very large proportion of hand tools whether these be razors, knives, paring chisels or similar wood-working tools, act as saws, that is to say, they are used with the greatest efficiency when the cutting edge is not held and forced at right angles to the direction of the cut, but is drawn through it so that its edge, which is always more or less serrated, acts as a saw; all saws therefore may be classed with this variety of cutting action, which we may call slicing.

The force required for cutting any class of material depends on the softness of the material operated on, and on the angle of the cutting edge of the appliance used. It is useful here to give a list of the angles of cutting edges that are in common use.

Angles for Cutting Edges of Tools or other Cutting Appliances.

90°—70°	Tools fixed in machine tools, also all shears, punches and other hand tools, and especially for machine tools used on chilled cast-iron.
70°—60°	For machine tools used for moderately hard metals, hammers and chisels used on stonework, hand or chipping chisels used on metal-work.
60°—50°	Hand-turning tools used on hard wood or ebonite.
50°—40°	Cutting edges of axes, adzes, choppers or similar tools used percussively on woodwork.
40°—30°	For tools driven by a mallet, carving, graving and similar tools used on woodwork.
30°—25°	For plane irons, spoke shaves, draw knives used on woodwork.
25°—20°	For wood-working tools used by hand pressure.
20°—18°	For carving, pruning and other knives with a slicing action.
18°—16°	Used with the finest cutting, such as surgeons' knives, penknives, &c., also used with the drawing or slicing action.
17°—16°	Hand razors ditto ditto ditto.
16°—15°	Safety razors ditto ditto ditto.

There is little doubt that this series of cutting angles is the result of long experience: but we have now to consider whether the great increase of transverse strength which is now obtainable in cutting edges formed from the new H.S. steels will enable us to reduce these angles and thus diminish the force required to force them through the material we are cutting. Before we can consider this it is necessary to call attention to the causes which limit the durability of the cutting edge, in other words the rate at which it becomes blunt when in use. So soon as the microscope is brought into use to examine a blunted cutting edge it is seen that in all cases the bluntness consists in the crumbling or breaking away of the thin edge. This blunting action proceeds by progressive serration, at first very small gaps appear in the edge, thus leaving projecting teeth. When such a cutting edge is used for a slicing cut such as in a carving knife or a scimitar, this serration, so long as the teeth are small, does not diminish the cutting efficiency, but as the use is continued the teeth formed between the first gaps break away, generally forming a second series of serrations rather larger than the first series, and this goes on until so much of the cutting edge is broken away that resharpening becomes necessary.

But when cutting edges are supported in a machine tool so as to be forced into the material cut, at a definite angle and steadily maintained at that cutting angle, the blunting of the cutting edge proceeds in a somewhat different fashion

Let us take the very common case of a lathe tool mounted in its tool post, and let us call that surface of the cutting edge which presses against the work A, the other surface, which is in most cases the upper surface, we will call B. Suppose that this tool is set to work and is traversed, as is usually the case, from right to left with a definite advance per revolution, the tool must be first forced into contact with the cylindrical surface that it is to cut, and in order to do this the surface A must be ground to what is called a clearance angle, usually of about 4° — 6°, which allows the cutting edge of the tool to take hold of, and commence splitting away a chip or shaving. The cutting angle of the tool is the angle between the surface A and the surface B, and we will suppose in this case it is originally ground to 60 deg. From the moment that the tool is set to work there is a tendency to wear away the surface A, and this wear, which ought to be very small—that is to say, if accurate diameter of the work is to be maintained—gradually alters the original line contact of the cutting edge, to a broader contact which is concentric with the finished work. This A surface has thus lost its clearance angle, and if the cut that is taken is a fine cut, and is stopped for any cause, it is not an easy matter to restart it again.

The wear on surface B is of an entirely different nature; it is chiefly caused by the friction of the strip or shaving cut away from the work, which curls away from the work from a point somewhat higher than the actual cutting edge, and thus protects the B side of the cutting edge from wear close to this point. The curling chip impinges on the B surface at some distance away from the edge, this distance depending on the speed of cutting; at high speed this distance is considerable. But from the very first moment that the cutting commences the wear due to the chip impinging on the B surface is of an important nature, as it gradually cuts a concavity which, as it deepens, gets somewhat closer to the surface A, until a point is reached at which the tool is so weakened by this groove on the B surface that it breaks away under the pressure of the cut acting on the point of the tool as a cantilever. When this occurs, which with the best H.S. steels does not occur until the tool has been at work for a long time, the breaking away of this surface necessitates the immediate removal of the tool so that it may be reground.

For a long time it was thought that this action of the actual cutting edge itself being protected on its upper surface was confined to H.S. steels, but the author's experience goes to show that this action occurs, however slow the speed is, with carbon steels equally with the H.S. steels; but in the case of the carbon steels, on account of their inferiority in transverse strength near the cutting edge, the crumbling action is liable to occur and the edge to break away at far earlier periods than with the H.S. steel.

The author has also noted that the same phenomenon occurs, although not to the same extent, with certain hand tools such as carpenters planes; in this case as in the case of the lathe tool the lower A surface wears but slightly, the upper surface scoured by the shaving wears with considerable rapidity, and for this reason we find plane irons protected with a covering iron which serves to deflect the shaving, and thus protects the B surface from this important source of wear.

The author considers it probable that these two sources of wear can be observed in all tools used for paring away shavings or chips. In the two classes of cases which have been considered it will be seen that the tool fails from the crumbling away of the edge. This crumbling action is increased when the tool is not steadily pressed against the material cut, but as is often the case with hand tools, is driven forward by a series of blows of a mallet or hammer, the tendency for the edge to crumble is thus increased, and in the case of carbon steel can only be met by tempering the steel to a lower degree of hardness and hence increased toughness and by increasing the cutting angle. The great strength or toughness of the H.S. steels at the cutting edge enables them in all cases where they are used in machine tools to do the same work as the carbon steel with a largely reduced cutting angle or by reducing the power required to drive them over the material, reducing the heat of friction at high speeds, and thereby greatly reducing the cost of cutting.

Turn to the table of angles given, it is found that the angles for cutting tools used not only in machine tools but also in hand tools might, if H.S. steels be used, be decreased from 26 per cent. to 25 per cent. In practice it is found that chipping chisels used for trimming castings which usually are ground from an angle of from 75° to 65° may have this angle reduced to 45° if a steel containing 4 per cent. nickel, 1 per cent. chrome and 0·4 per cent. carbon be used for these chisels. It is therefore reasonable to suppose that if, as appears to be the case, some of the H.S. steels can actually be hardened to the same degree of cutting hardness as the best carbon steels, it may be hoped that all the remaining angles given in the table for hand tools may be largely reduced, and that there is a reasonable prospect that those for planes and chisels may be reduced to 30° for hard woods and for soft woods to 20°, and for fine slicing, cutting of surgeons' knives, penknives and the like from 18° to 15°, and for razors from 16° to 12°, or even 10°. But these fine angles are largely a question of new design of apparatus for grinding and polishing the edges without bending them.

* Paper read before Section G of the British Association, August 24, 1920.

Floating Docks at Schiedam. The largest floating dock in Europe with a lifting capacity, it is stated, of 50,000 tons, has been purchased by Holland from Austria, and has recently arrived at Schiedam, where it will be located for the future. Another floating dock has also been brought to Schiedam from Hamburg.

THE EFFECT OF TEMPERATURE ON SOME OF THE PROPERTIES OF MATERIALS.*

By Professor F. C. Lea, O.B.E., D.Sc., M.Inst.C.E.

The use of materials, subject to stress at temperatures much higher than the normal, in steam plants, internal combustion engines, &c., necessitates a knowledge of the effect of temperatures upon the properties of materials. It is by no means wise to assume that a material peculiarity well suited to meet certain conditions at ordinary temperatures is able to perform the same duty at higher temperatures. In the early days of the war it was found that a certain alloy of aluminium containing 13 per cent. of zinc and 3 per cent. copper gave good results at ordinary temperatures, and it was suggested that it should be used for pistons of internal combustion engines. Failure ensued, and it was then found that the strength and hardness of this alloy changed very rapidly so that at 300 deg. C. it was very weak and soft and quite unsuited to meet the conditions that obtain in a petrol engine cylinder. The very serious accident that happened on the Lancashire and Yorkshire Railway some years ago to a locomotive fire box emphasised the same lesson, and in connection with the use of certain alloys for high pressure, or highly superheated steam valves, difficulty has been experienced. Another very important engineering and architectural problem to which we propose to refer later, viz., the construction of fireproof buildings would no doubt have been more adequately solved, if greater attention had been directed to the scientific investigation of the effect of temperature on certain materials.

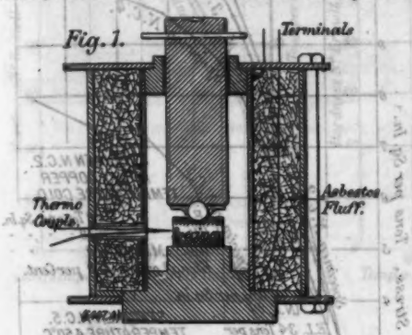
In 1914 the author presented a paper to Section "G" of the British Association and gave results of certain experiments that had been carried out at Birmingham. The war has intervened and temperature difficulties in connection with pistons, cylinders, springs, valve seats and other details made it desirable that the work begun in 1913 should be continued. It is not the object of this paper to describe in detail these experiments,* but rather to refer to a few special points.

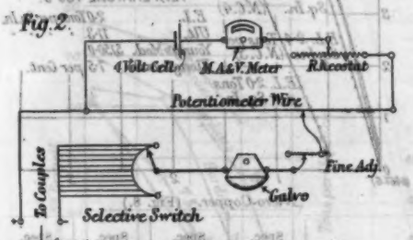
The experiments on metals have included *inter alia* tensile tests, and hardness tests at temperatures varying from 0 deg. C. to 900 deg. C. in the former case and to 500 deg. C. in the latter. From the tensile tests have been obtained :—

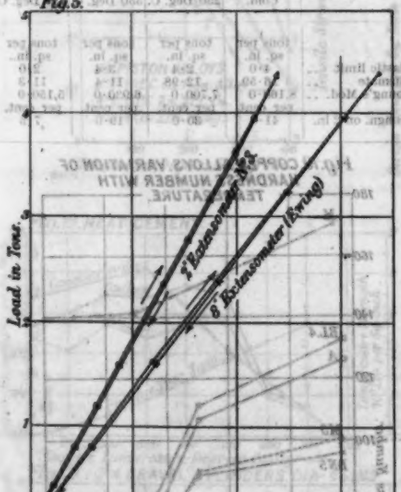
(1) The breaking strength.
(2) The elastic limit.
(3) The yield point (when possible).
(4) The Modulus of elasticity.
(5) Elongation per cent.
(6) Reduction of area at fracture, for a number of metal.

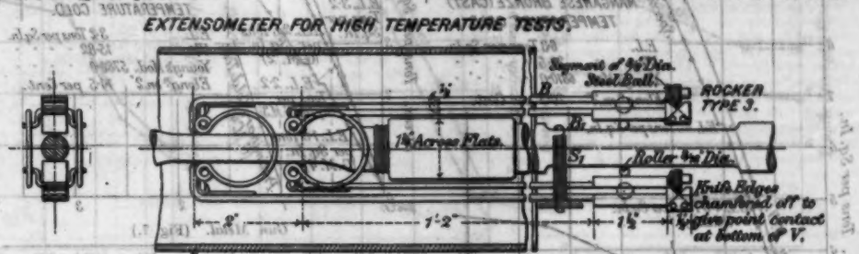
The tests have been carried out in electrically-heated furnaces. One furnace used has a porcelain tube 2½ in. diameter, 24 ins. long wound with a platinum strip. Such furnaces are expensive and satisfactory porcelain tubes are not easy to get. By far the greater portion of the tests have, however, been carried out in furnaces made in our own laboratory, and the one mostly used consists of a steel tube 4 ins. outside diameter, ½ in. thick, wound non-inductively with nichrome wire. This is insulated from the steel tube by strips of Uralite laid along the tube. The whole is encased in asbestos wool, and a covering tube of tin, which is again covered with asbestos cloth. Two circular plates held together by 4 bolts, and to which the terminals suitably insulated are connected, complete the ends of the furnace. No trouble has been experienced with these furnaces even when working with temperatures well over 700 deg. C. For the hardness tests the furnace shown in Fig. 1 was constructed. This is very similar in construction to the furnace just described except that at one end, it has a heavy anvil and at the other end, a guide for the plunger. When being used on the Brinell machine, the anvil is insulated by asbestos. A standard steel ball 10 mm. diam. is attached to the plunger. A small transverse tube pierces the cylinders of the furnace to allow the thermo-couples to enter the furnace conveniently. Temperatures were generally measured by iron-constantin or Cu-Constantin thermo-couples. The couples were calibrated in the usual way by taking cooling curves of suitable metals. For measuring furnace temperatures direct reading instruments were sometimes used, but more generally the arrangement shown in Fig. 2 was adopted. When taking extensometer readings it is very desirable that temperatures should be maintained as constant as possible. This is more important than that the temperature should be measured with a high degree of precision.

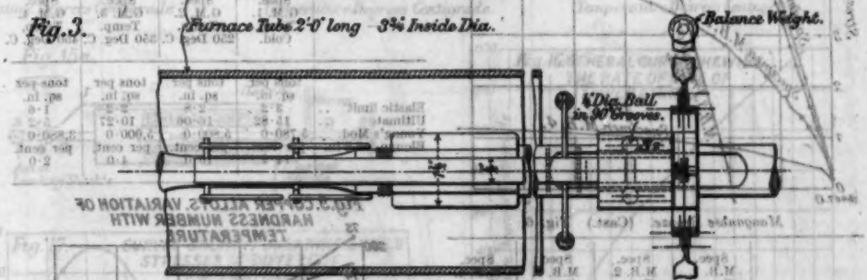
Extensometers.—A number of forms of extensometers have been developed. One of the latest, for use in a horizontal testing machine is shown in Fig. 3. There are two bars B and B_1, on each side of the specimen, each with a knife edge resting on the specimen at 2 in. apart. The two bars B, one above and one below the specimen, are gripped to the specimen by the loop springs one on each side of the specimen. Bars B_1 are gripped in a similar manner. At the end of B which comes outside the furnace is fixed a table which rests on a roller resting on the rod connecting the specimen to the shackle of the machine. This table has V grooves in which are placed steel balls ¼ in. diameter. To the end of B_1 is also fixed a table with grooves for the ¼ in. diameter balls. The bars B and B_1 can, therefore, move relatively to each other with perfect freedom. The rocker, Fig. 3, consists of a knife edge resting in Va. fixed to the table connected to B_1. This rocker has at its centre the segment of a ball which always rests against the end of the table B. There is a similar rocker below the specimen. Each of the rockers carries a mirror; the rotations of the mirrors give a measure of the extensions on the respective sides of the specimen and the mean gives the axial extension. Only one scale and telescope is used, the two mirrors being arranged so that there is reflection from the one to the other. In Fig. 4 are shown two other types of rockers that have been used. It is quite easy to attach micrometers to the tables for calibrating the instrument, but it was found more convenient to use a special[1] calibrating device for this purpose and the instrument was also compared with a Ewing 8-in. extensometer; the two instruments being placed in series on one bar. Fig. 6 shows the stress strain curves obtained from the two instruments. Typical stress strain curves taken at various temperatures for three metals are shown in Figs. 6 to 8.








EXTENSOMETER FOR HIGH TEMPERATURE TESTS.
Segment of ¼ Dia. Steel Ball.
ROCKER TYPE 3.
1¼ Across Flats.
Roller ¼ in Dia.
Knife Edges chamfered off to give point contact at bottom of V.
2"
1'-2"
1½"



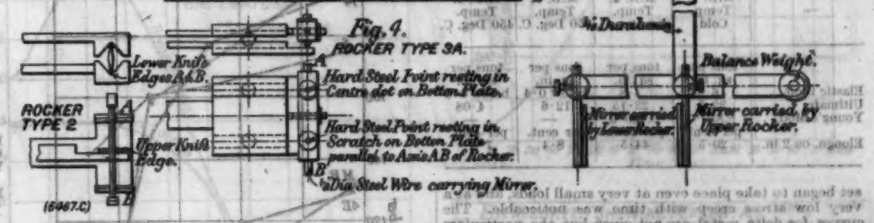


Fig. 4.
ROCKER TYPE 3A.
Lower Knife Edges A & B.
Hard Steel Point resting in Centre dot on Bottom Plate.
ROCKER TYPE 2
Upper Knife Edge.
Hard Steel Point resting in Scratch on Bottom Plate parallel to Axis AB of Rocker.
Balance Weight.
Mirror carried by Lower Rocker.
Mirror carried by Upper Rocker.
¼ Dia. Steel Wire carrying Mirror.

There are a number of interesting points which are at once apparent from these diagrams. None of the alloys, even at ordinary temperatures, show any very definite yield until long after the elastic limit of the material has been passed. In fact, of nearly all the alloys, it can be said that yield point as usually understood has no real meaning. The effect of temperature on the elastic modulus and on the form of the stress strain curve is very noticeable and in some cases may be more important than the effect on the ultimate strength. For example, the strength of manganese bronze is reduced from 32·5 tons per square inch at ordinary temperatures to 12·6 per square inch at 350 deg. C., while its elastic limit is reduced from 6·3 tons per square inch to less than 0·4 tons per square inch. Permanent

TABLE I.—*Delta Metal.*

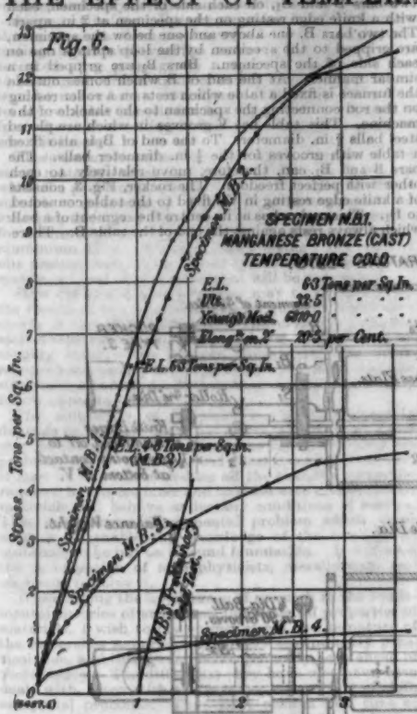
Temperature.	Ultimate Strength.	Modulus of Elasticity.	Elastic Limit.
	tons per sq. in.	tons per sq. in.	tons per sq. in.
15	32·65	6,899	4·6
250	28·0	6,290	2·8
350	18·6	5,870	0·8
450	7·32	No definite value	less than 0·2

* Paper read before "G" Section of the British Association, August, 1920.

* *See* Proc. Roy. Aeron. Soc., November, 1919. Paper by F. C. Lea.
See also Proc. Inst. C.E., 1919–20. Paper by F. C. Lea.
See also Memorandum written by Professor C. F. Jenkin.

* *See* Proc. Inst. Civil Eng., 1919–20.

THE EFFECT OF TEMPERATURE ON SOME OF THE PROPERTIES OF MATERIALS.



Manganese Bronze. (Cast.) Fig. 6.

—	Spec. M.B. 1. Temp. Cold.	Spec. M.B. 2. Temp. 250 Deg. C.	Spec. M.B. 3. Temp. 350 Deg. C.	Spec. M.B. 4. Temp. 450 Deg. C.
	tons per sq. in.	tons per sq. in.	tons per sq. in.	tons per sq. in.
Elastic limit ..	6·3	4·8	below 0·4	below 0·4
Ultimate ..	32·5	23·15	12·6	4·08
Young's Mod. ..	6,810·0	6,140·0	—	—
	per cent.	per cent.	per cent.	per cent.
Elongn. on 2 in.	20·5	44·5	8·4	7·0

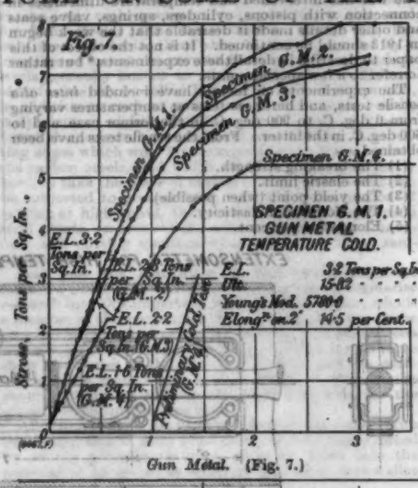
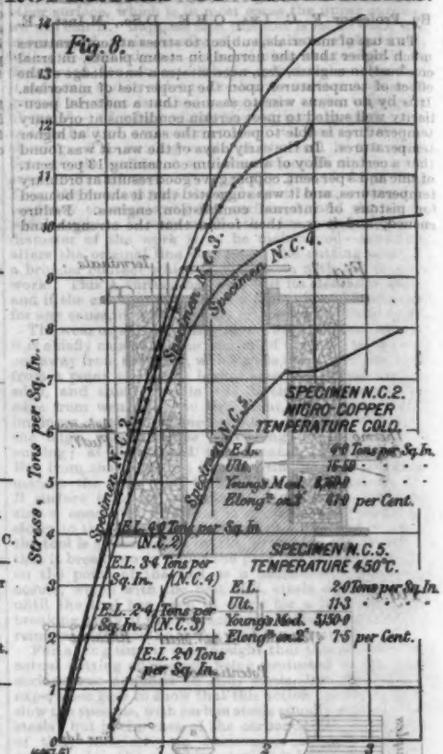


Fig. 7.
Specimen G.M.1.
Specimen G.M.2.
Specimen G.M.3.
Specimen G.M.4.
SPECIMEN G.M.1.
GUN METAL
TEMPERATURE COLD.
E.L. 3·2 Tons per Sq. In.
E.L. 2·8 Tons per Sq. In. (G.M.2)
E.L. 2·2 Tons per Sq. In. (G.M.3)
E.L. 1·6 Tons per Sq. In. (G.M.4)
Stress, Tons per Sq. In.
E.L. 3·2 Tons per Sq. In.
Ult. 15·62 · · · ·
Young's Mod. 5780·0
Elong% on 2" 14·5 per Cent.

Gun Metal. (Fig. 7.)

—	Spec. G.M. 1. Temp. Cold.	Spec. G.M. 2. Temp. 250 Deg. C.	Spec. G.M. 3. Temp. 350 Deg. C.	Spec. G.M. 4. Temp. 450 Deg. C.
	tons per sq. in.	tons per sq. in.	tons per sq. in.	tons per sq. in.
Elastic limit ..	3·2	2·8	2·2	1·6
Ultimate ..	15·62	16·06	10·27	5·2
Young's Mod. ..	5,780·0	5,800·0	5,000·0	3,880·0
	per cent.	per cent.	per cent.	per cent.
Elongn. on 2 in.	14·5	16·0	4·0	2·0



Nicro-Copper. (Fig. 8.)

—	Spec. N.C. 2. Temp. Cold.	Spec. N.C. 3. Temp. 250 Deg. C.	Spec. N.C. 4. Temp. 350 Deg. C.	Spec. N.C. 5. Temp. 450 Deg. C.
	tons per sq. in.	tons per sq. in.	tons per sq. in.	tons per sq. in.
Elastic limit ..	4·0	2·4	2·4	2·0
Ultimate ..	16·59	12·98	11·4	11·3
Young's Mod. ..	8,100·0	7,700·0	6,930·0	5,150·0
	per cent.	per cent.	per cent.	per cent.
Elongn. on 2 in.	41·0	30·0	19·0	7·5

set began to take place even at very small loads, and at a very low stress creep with time was noticeable. The curves for delta metal are not given but the particulars in Table I are of interest.

Ultimate Strength and Hardness.—The author thinks he may claim to have been the first to determine the hardness numbers of metals at high temperatures. The furnace Fig. 1 has been used in these determinations.

The results obtained are of very considerable interest in connection with nearly all the alloys. Figs. 9 and 10 show the hardness numbers obtained for a number of alloys at various temperatures. It will be seen from Fig. 10 that alloys of copper and nickel M and Mc maintain their hardness to a temperature of 450 deg. in a remarkable manner while nearly all the ordinary copper alloys diminish very rapidly in hardness at temperatures beyond 250 deg. C. As will be seen from the figure nickel steel maintains its hardness better than all the alloys except the two mentioned. Figs. 11 to 15 show, for a number of alloys, the change of hardness and of the tensile strength with temperature.

There is a striking similarity between the curves in all cases. The curve of tensile strength for monel metal is not given but the author has shown elsewhere* that its strength, elastic limit and modulus of elasticity are, exactly like the hardness affected to a much less degree by temperature than the same quantities for the other copper alloys.

At 500 deg. C. its breaking strength, elastic limit and modulus of elasticity are all more than 90 per cent. of the same quantities at ordinary temperatures. Fig. 14 shows how both hardness and breaking strength are maintained by nicro-copper, which contains only 2 per cent. of nickel.

Aluminium Alloys.—The use of aluminium alloys for parts of motor car and aeroplane engines has made it necessary to inquire carefully into the effect of temperature on such alloys. Details of investigations into these alloys are given in a paper read before the Royal Aeronautical Society in 1919. It is sufficient to say here that copper, manganese, nickel and magnesium have a considerable effect in hardening aluminium alloys, and increasing their strength at temperatures above 150 deg. Fig. 15 shows the hardness and tensile strength of a 10 per cent. copper alloy and the hardness curves for two other alloys. The high percentage zinc alloys diminish in hardness so rapidly that they are not of much

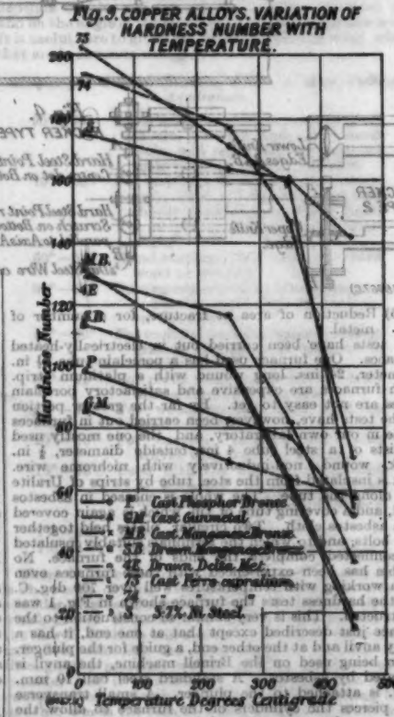


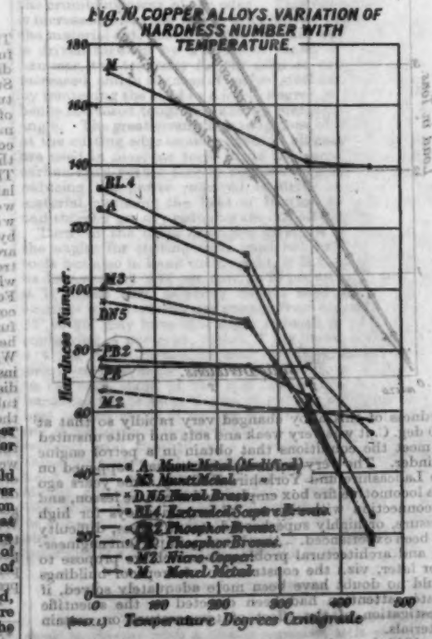
Fig. 9. COPPER ALLOYS. VARIATION OF HARDNESS NUMBER WITH TEMPERATURE.
Hardness Number
Temperature Degrees Centigrade
P Cast Phosphor Bronze
GM Cast Gunmetal
MB Cast Manganese Bronze
3E Drawn Muntz Metal
4E Drawn Delta Met.
75 Cast Ferro cupralum.
S 5·7% Ni. Steel.

use for pistons. Alloys that maintain a hardness number of, say, 28 at 300 deg. C. appear to be quite suitable for pistons and have given good results in flight.

Alloys containing from 8 to 12 per cent. of Cu should give this hardness number, and those containing lower percentages of Cu with nickle and magnesium, or iron and magnesium, give much higher hardness numbers at this temperature. They are, however, much more troublesome in the foundry. At the temperature of 300 deg. the hardness is practically independent of whether the alloy has been sand or chill cast.

Steel and Reinforced Concrete.—As already remarked, the importance of studying the effects of temperature on materials, becomes significant in connection with the attempts made to construct fireproof buildings.

In this country*, in America and in Germany a very large amount of money has been spent in large size experiments on concrete and re-inforced concrete to determine the effect of fire upon these materials and to obtain if possible data as to details of design and the



* Proc. Inst. Civil Engineers, 1919–20.

* See Red books of the British Fire Prevention Committee about to be issued by H.M. Stationery Office.

best aggregates to be used for making reinforced concrete fireproof buildings.

In the author's opinion it is very doubtful if a good deal of this money has been wisely spent. As in many other cases, expensive tests have been undertaken before the fundamentals of the problem have been investigated. On being requested some time ago to serve on the British Fire Prevention Committee and to see the tests this committee was carrying out, it seemed perfectly clear that it was desirable to consider under what conditions reinforced concrete would be sure to fail when exposed to fire, and the immediate answer seemed to be, whenever the steel reached such a temperature that its yield point was less than the stress to which the steel was subjected when the beams and slabs were carrying the loads for which they were designed. That is, if the reinforced concrete beams and slabs of a building were designed to have a working stress in the steel of, say, 7 tons per square inch then, if during a fire the steel could, by any means, reach a temperature at which the yield point was less than this, the floors would be bound to collapse. What this temperature would be could be found by a laboratory experiment. This data having been obtained the next step would appear to be the determination, if possible, of those kinds of concretes which would stand much higher temperatures than this and which would give a sufficient thickness of coating to the steel to prevent the steel, under the conditions of a vigorous fire, from reaching this temperature. This immediately introduces a number of questions of very considerable interest. What is the effect of high temperature on cement itself? How is a concrete which is an agglomerate made up of at least three different materials, cement, sand or small aggregate and large aggregate likely to behave under rapid changes of temperature? The possibility of the three materials having different ratios of expansion, of hygroscopic and chemical changes taking place as well as the concrete having a different ratio of expansion from the steel all affect the problem.

The first experiments we propose then to describe are of the nature of preliminary tests made in the hope of throwing some light upon this problem.

Figs. 15 to 18 show results obtained from tests of mild steel which had actually been supplied for reinforced concrete. The breaking strength at zero degrees centigrade was 30 tons per square inch. The maximum strength was obtained at about 235 deg. C. No attempt was made to determine this actual temperature with very great precision but from other experiments on quenched and tempered steels (by the author*) containing from 0·48 per cent. carbon to 1·2 per cent carbon there seems every indication that at about this temperature, a "peculiar" point occurs on the curve of breaking strength.

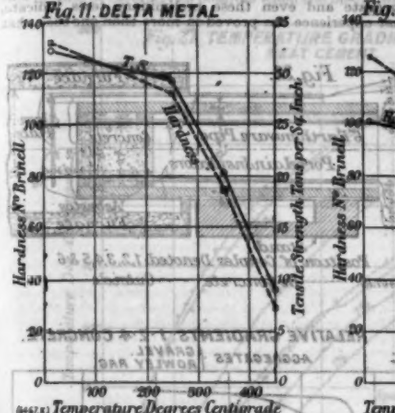
At temperatures beyond 300 deg. C. the strength diminishes very rapidly and at a temperature from 615 deg. to 640 deg. C. the breaking strength is less than 7 tons per square inch. The actual temperature at which the fracture takes place at this stress depends upon a time factor of heating and loading.

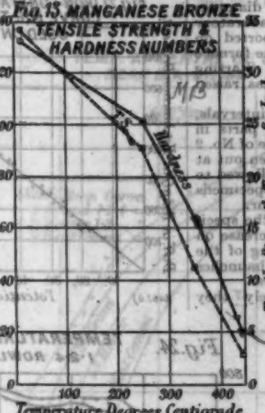
On Fig. 17 are shown two coinciding points not on the curve. These points were obtained by loading bars with a stress of 15,000 lb. per square inch and gradually raising the temperature of the specimens until they broke. The other points on the curve were obtained by bringing the specimen to a steady temperature, maintaining it at this temperature for 20 minutes and then breaking. It will be seen from these curves that the breaking strength of the steel reaches the design working stress of 7 tons per square inch at a temperature very little more than 600 deg. C., and there seems no doubt that if the beams and slabs are fully loaded failure is bound to take place when the steel reaches a temperature approximating to 650 deg. C. This then is a fundamental fact of importance in considering this question of fire prevention. If the concrete covering is too thin, or if it cracks and fritters under the temperature to which it is exposed, then the steel must quickly reach the dangerous temperature. On the other hand, if the steel can be kept below this dangerous temperature for a certain length of time, during which the worst part of the fire may have spent itself then the building is likely to survive.

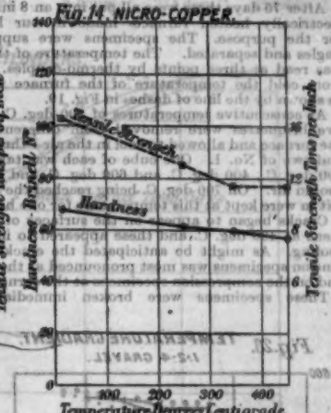
It is well known that the tensile strength of concrete is not at all depended upon in reinforced concrete structures, but it seemed not without interest to determine the effect of heating to a certain temperature on the breaking strength of cement in tension and compression, and concrete in compression.

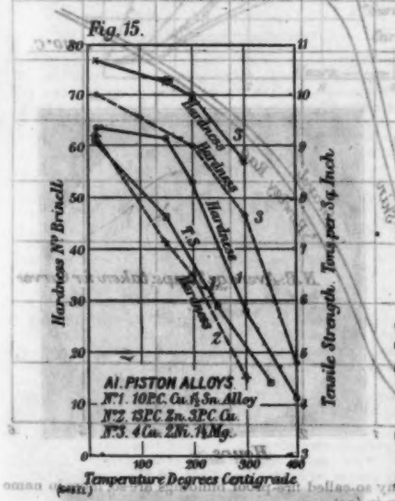
The columns of a structure are likely to be subjected to the highest temperatures of the fire, and if certain temperatures are passed both steel and concrete may fail.

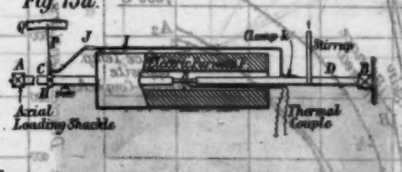
Two lots of A. P. Cement were made into briquettes and 2 in. cubes as given on the next page:

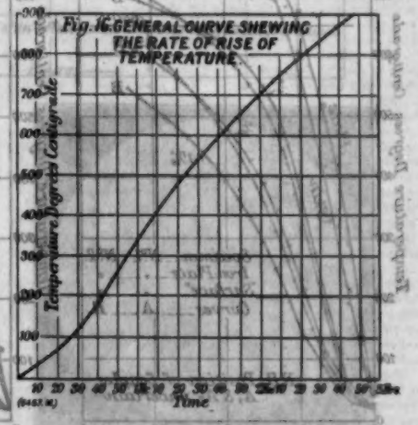












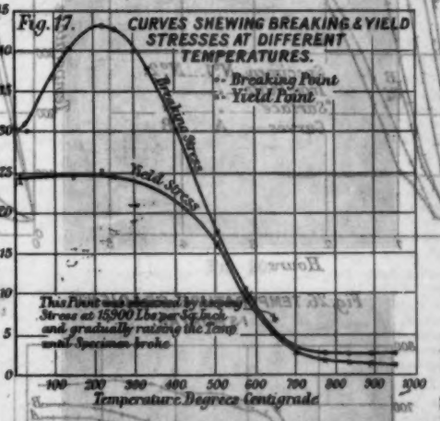


Fig. 17. CURVES SHEWING BREAKING & YIELD STRESSES AT DIFFERENT TEMPERATURES.
Breaking Point
Yield Point
Breaking Stress
Yield Stress
This Point was obtained by loading Stress at 15000 Lbs per Sq. Inch and gradually raising the Temp. until Specimen broke
Stress Tons per Sq. Inch
Temperature Degrees Centigrade.

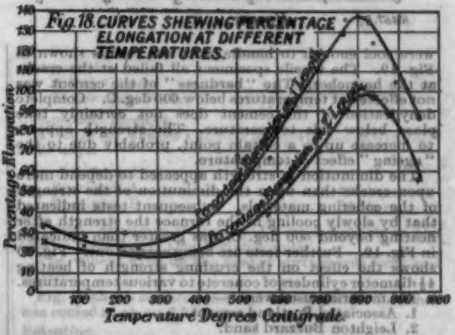
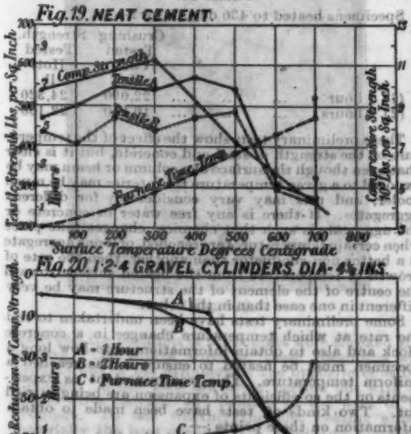
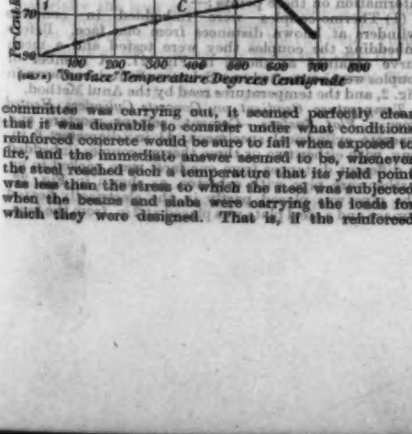


Fig. 18. CURVES SHEWING PERCENTAGE ELONGATION AT DIFFERENT TEMPERATURES.
Percentage Elongation
Temperature Degrees Centigrade.





* Proc. Inst. Civil Engineers, 1919-20.

1. 3,500 grams cement and 840 c.c. of water at 16 deg. C. to 24 deg. C.
(a) 20 briquettes, 1 in. waist.
(b) Four 2 in. cubes.
2. 5,000 grams cement, 1,200 c.c. of water at 16 deg. to 24 deg. C.
(a) 32 briquettes.
(b) Four 2 in cubes.
All stored in water after 24 hours.

After 75 days these were all put into an 8 in. diameter electrically heated furnace made in our laboratory for the purpose. The specimens were supported on angles and separated. The temperature of the furnace was read at three points by thermo-couples. Starting from cold the temperature of the furnace was raised as shown by the line of dashes in Fig. 19.

At consecutive temperatures of 100 deg. C. intervals, five briquettes were removed from different parts in the furnace and allowed to cool in the air—three of No. 2 and two of No. 1. One cube of each was taken out at 200 deg. C., 400 deg. C. and 600 deg. C. and allowed to cool in air. On 700 deg. C. being reached the specimens left in were kept at this temperature for one hour.

Cracks began to appear on the surfaces of the specimens at 400 deg. C., and these appeared to increase on cooling. As might be anticipated the cracking of the tension specimens was most pronounced at the haunches and on the compression specimens at the corners.

These specimens were broken immediately they were cool enough to handle, with the results shown in Fig. 19. The tensile specimens all failed at the cracks at the haunches. The "hardness" of the cement was not effected at temperatures below 600 deg. C. Complete dehydration of the cement does not certainly take place below this temperature. The strength appears to increase up to a certain point, probably due to the "ageing" effect of temperature.

The diminution in strength appeared to depend more upon cracks than upon the diminution of the strength of the cohering materials. Subsequent tests indicated that by slowly cooling in the furnace the strength after heating beyond 500 deg. C. was greater than indicated in Fig. 19. Further tests are being carried out. Fig. 20 shows the effect on the crushing strength of heating 4½ diameter cylinders of concrete to various temperatures.

The materials used were :—
1. Associated Portland cement.
2. Leighton Buzzard sand.
3. ¼ in. to ¾ in. gravel from Water Orton and 8·4 per cent. of water.

Twenty-four cylinders were made in four lots of six each. They were stored in the usual manner at a temperature from 50 deg. to 60 degs. Fahr. Preliminary tests on two specimens were made, one unheated and the second heated to 750 deg. C. in a muffle of a Mond gas furnace. The latter had only 5 per cent. of the strength of the former.

The 24 specimens were then dealt with as follows :—

Two out of each six were tested cold. The remaining four of the same batch were heated to a specific temperature in the special* electrically heated furnace. The four specimens were put in series to form one cylinder, on two angles in the furnace, the ends being protected by two other cylinders of the same diameter. Temperatures were taken by thermo-couples, touching the specimens. The time-temperature curve for the furnace is shown by the dotted curve Fig. 20. When the required temperature was reached the current was adjusted to keep this constant within 10 deg. C. The cylinders were taken out either one hour or two hours after this adjustment. Cracks commenced on specimens heated for one and two hours at 430 deg. C. On cooling the cracks became more noticeable. The effect of the temperature on the crushing strength is shown in Fig. 20. At 590 deg. C. the crushing strength of the concrete is only 20 per cent. of its original strength. Up to about 450 deg. C. the concrete appears to be little affected by the heating and above this temperature the falling off in strength appears to be very largely due to loss of bond between the materials. It is of interest to notice that blocks heated to 430 deg. C. and tested while hot were, as shown in Table II, stronger than two other blocks heated to the same temperature and allowed to cool. The number of these tests is not sufficient to prove anything definite, but they do probably indicate that loss of strength is very largely due to cracks that develop further as the specimen cools. The loss of weight of the blocks was quite small. After heating to temperatures higher than 430 deg. C. the pebbles could be picked out of the mass clean. Specimens of other aggregates have been prepared for test.

A very large number of buildings have been built in various parts of the country, using gravel in the large aggregate and even these preliminary tests indicate, what experience has proved in more than one case, that many so-called fire-proof buildings are so, more in name than in fact.

* Experiments were in progress as to whether electric heating produces different results to those produced by hot gases.

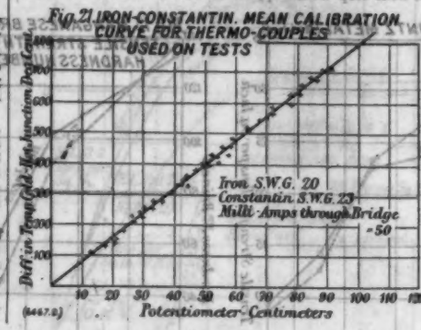
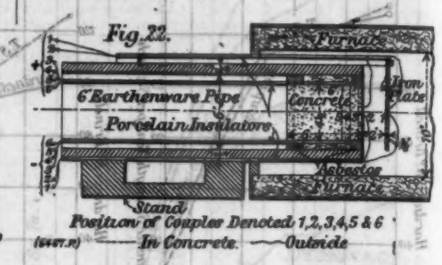
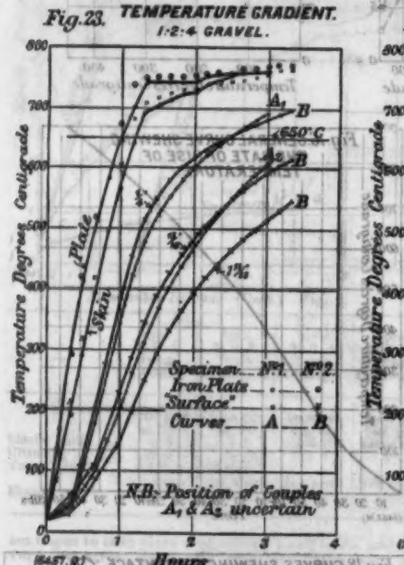
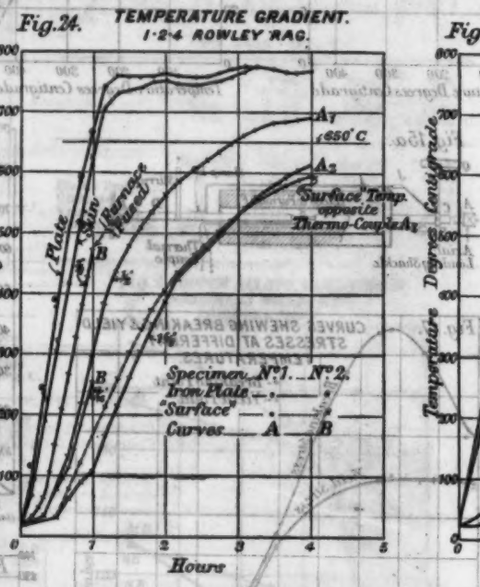
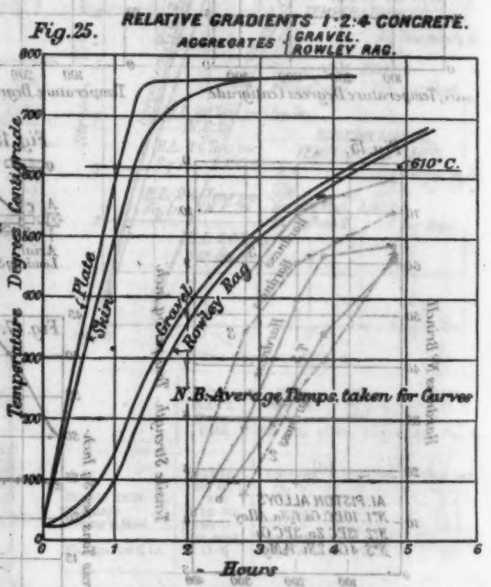


Fig. 21. IRON-CONSTANTIN. MEAN CALIBRATION CURVE FOR THERMO-COUPLES USED ON TESTS
Iron S.W.G. 20
Constantin S.W.G. 23
Millt. Amps through Bridge = 50
Potentiometer Centimeters









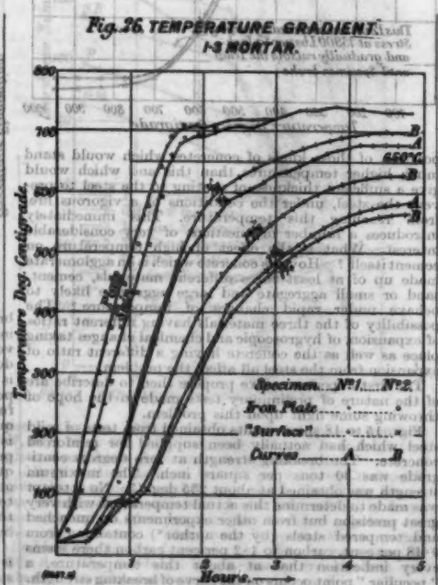


TABLE II.

Specimens heated to 430 deg. C. for 5 hrs.

	Crushing Strength. Tested Cold. lb.	Tested Hot. lb.
(1) 1 hour	22,090	24,320
(2) 2 hours	19,840	22,100

These preliminary tests show the effect of the temperature on the strength of steel and concrete, but it is clear that even though the surface of a column or beam may be exposed to a given temperature the interior may be much cooler, and this may vary considerably for different aggregates. If there is any free water in concrete or the aggregate is such that chemical changes take place when certain temperatures are reached, or if one aggregate is a better non-conductor than another, then the rate of growth of temperature from the heated surface toward the centre of the element of the structure may be very different in one case than in the other.

Some preliminary tests have been undertaken to test the rate at which temperature changes in a concrete block and also to obtain information as to how long a specimen must be heated to ensure it has reached a uniform temperature. This was important as experiments on the co-efficients of expansion are being carried out. Two kinds of tests have been made to obtain information on these points :—

(1) Thermo-couples were imbedded in concrete cylinders at known distances from one face. Before imbedding the couples they were tested and a mean curve obtained as shown in Fig. 21. A number of couples were connected to a Selective Switch as shown in Fig. 2, and the temperatures read by the Anul Method.

Temperature Gradient on Concrete Cylinders Heated from a Flat Surface.—Cement, cement mortars and concrete cylindrical specimens, 4½ in. diameter, 6 in. long, with either two or three thermo-couples imbedded at different distances from one face, were packed in an earthenware pipe with asbestos, as shown in Fig. 22. The pipe was placed partly in the electrically-heated furnace and a steel plate was placed at 2 in. from the face.

This plate took up the temperature of the furnace and radiated heat to the concrete surface. Thermo-couples were made to touch the plate and the face of the concrete. The temperature of the plate, the furnace near the surface of the specimen and of the couples within the specimen could be read simultaneously.

The results of the tests are shown in Figs. 23 to Fig. 27. The cylinders marked A contained two thermo-couples only, while B contained three thermo-couples. These were located as carefully as possible when the blocks were made and the positions of the couples were checked after heating. The couple wires in these specimens were brought out of the cylinders at the opposite ends of a diameter. Other tests are being carried out with the couple wires brought out parallel to the axes of the cylinders. To test whether the first heating altered materially the heat gradient the specimens marked A were subjected to a second heating. The results obtained were not very different in the two tests. Further particulars of the cylinders are given in TABLE III.

TABLE III.—*Particulars of Concrete and Cement Blocks.*

I. 1 : 2 : 4 gravel.

Composition.

Aggregate—Gravel	4	By weight.
Leighton Buzzard Sand ...	2	
A.P. Cement	1	
8·4 per cent. Water		

Compressive Strength.

Average for 6 cubes 4 in. by 4 in. by 4 in.—2,200 lb./in.² at 60 days.

Ages when heated.

Specimen A	49 days.
Specimen B	51 days.

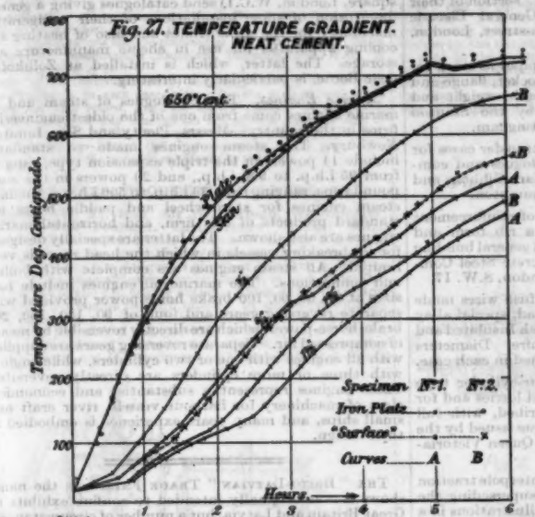
NOTE.—The exact location of the couples in A by measurement after test was difficult, due to softness of surface.

Fig. 29 shows surface after one heating.
„ 30 „ „ second „
Aggregate comes away clean from matrix.

Fig. 31 shows surface after heating.
Fig. 32 shows crack developed in side on cooling.
The matrix aggregate could easily be separated by the finger.

Reheating.

	Time.	Temperature of Plate.	Temperature 1½ in.
1st heating ...	2 hours.	755 deg. C.	375 deg. C.
2nd heating ...	2 hours.	775 deg. C.	425 deg. C.



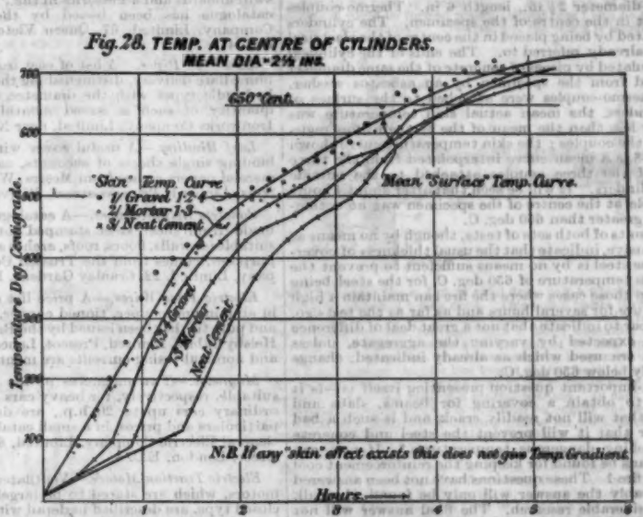


Fig. 28. TEMP. AT CENTRE OF CYLINDERS.
MEAN DIA. = 2½ INS.
650° Cent.
"Skin" Temp. Curve
1/ Gravel 1:2:4
2/ Mortar 1:3
3/ Neat Cement
Mean "Surface" Temp. Curve.
Temperature Deg. Centigrade.
Hours.
N.B. If any "skin" effect exists this does not give Temp. Gradient.

FIG. 29.

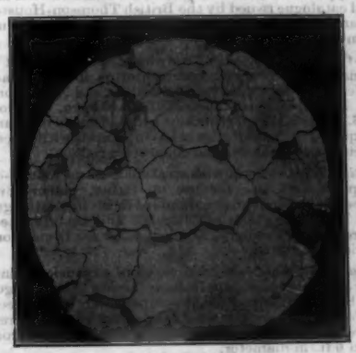


FIG. 30.

FIG. 31.

FIG. 32.

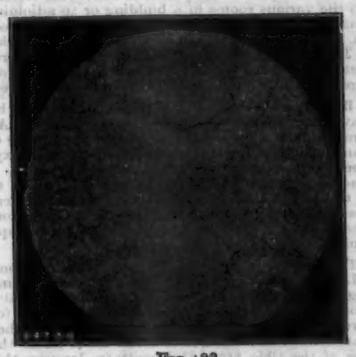


FIG. 33.

Reheating.

	Time.	Temperature of Plate.	Temperature (1½ in.)
1st Heating ...	1½ hours.	730 deg. C.	350 deg. C.
2nd „ ...	1½ hours.	730 deg. C.	345 deg. C.

II. 1 : 2 : 4 Rowley Rag.

Composition.

Aggregate, Rowley Rag ...	4	By weight.
Leighton Buzzard Sand ...	2	
A.P. Cement	1	
8·4 per cent. water		

Compressive Strength.

Average three 4 in. by 4 in. by 4 in. cubes—1,900 lbs./in.² at 32 days.

Ages when heated.

Specimen A	31 days.
Specimen B	32 days.

NOTE.—The incompleteness of curves for B was due to furnace failure. The temperature on the cylindrical surface opposite inside couple is shown dotted.

Neat Cement.

Composition.

A.P.C. Cement		By weight.
24 per cent. Water		

Compressive Strength.

Average for 4 cubes 4 in. by 4 in. by 4 in.—5,000 lb./in.² at 35 days.

Ages when heated.

Specimen A	39 days.
Specimen B	39 days.

NOTE.—Specimen B developed a crack right down the axis on the plane of the thermo-couples.

The cement even on the heated surface was hard and brittle.

Fig. 33 shows surface after 2nd heating when specimen was cooled in about 2 hours.

Reheating.

	Time.	Temperature of Plate.	Temperature 1½ ins.
1st heating ...	2 hours.	475 deg. C.	100 deg. C.
2nd heating ...	2 hours.	520 deg. C.	200 deg. C.

It is interesting to note that in all cases the rate of rise of temperature of all the couples up to a temperature of 100 deg. C. was less than after 100 deg. C. had been passed, indicating that there was a little free water in all the specimens. There appeared little evidence of dehydration of the cement.

The thermo-couple on the face of the specimen gave probably a higher temperature than the real temperature of the surface. If temperatures are taken off the diagrams, after a certain period of heating, and curves, showing temperature plotted against distance of thermo-couple from the surface, are plotted it will generally be found that the surface couple temperature is above the heat gradient. This was anticipated as it is known to be very difficult to obtain a surface temperature when the surface is surrounded by air or other fluid at a higher temperature.

Time-Temperature Curves for a Point at the Centre of a Concrete Cylinder.—These tests were undertaken to find the time taken for the centre of a cylinder to reach the same temperature as the atmosphere of the furnace

immediately near the surface. Up to the present we have only been able to carry out a few tests, the results of which are shown in Fig. 28.

More instructive comparative results are expected from tests keeping the surface temperature constant instead of varying both temperature and time.

Three cylinders were tested :—

(1) 1 : 2 : 4 gravel concrete.
(2) 1-3 mortar.
(3) Neat cement.

Mean diameter 2¼ in., length 6 in. Thermo-couples were cast in the centre of the specimen. The cylinders were heated by being placed in the centre of the electrical furnace already referred to. The ends of the cylinders were insulated by pieces of concrete of the same diameter separated from the specimen by an asbestos washer. Three thermo-couples were attached to the surface of the cylinders, the mean actual skin temperature was probably less than the mean of the temperatures registered by the couples ; the skin temperature curve shown in Fig. 28 is a mean curve interpolated from the three curves of the three couples attached to the outside of the cylinders. It will be seen that after about 4 hours the couple at the centre of the specimen was at a temperature greater than 650 deg. C.

The results of both sets of tests, though by no means as yet conclusive, indicate that the usual thickness of covering for the steel is by no means sufficient to prevent the dangerous temperature of 650 deg. C. for the steel being reached in those cases where the fire can maintain a high temperature for several hours and as far as the tests go, they appear to indicate that not a great deal of difference is to be expected by varying the aggregate, unless materials are used which as already indicated, change chemically below 650 deg. C.

The all-important question presenting itself is—Is it possible to obtain a covering for beams, slabs and columns that will not readily crack, and is such a bad conductor that it will prevent the steel and concrete from reaching dangerous temperatures ? If not, can other means be found for keeping the reinforcement cool in case of fire ? These questions have not been answered and probably the answer will only be found, if at all, after considerable research. The final answer will not be found in the engineering laboratory, but as in other engineering problems, a good deal of light can be thrown upon this one by small scale laboratory experiments. As far as the steel is concerned, the tests detailed clearly indicate that its temperature must be kept below 650 deg. C. If some of the alloy steels ever become cheap enough and can be used for reinforced concrete, slightly higher temperatures may be allowable without risk of failure, but then advantage could not be taken of the high breaking strength of these alloys at ordinary temperatures if the failing stress under temperature is still to be 7 tons per square inch.

Such tests as those we have described indicate what is to be aimed at, and it may be that they may indicate the best aggregates to be used and the thickness of covering for protecting the steel, or at least may indicate the materials upon which it is worth while carrying out large scale experiments.

The whole question of the influence of temperature on materials is clearly of importance to the engineer. The results obtained from the tests on metals are also of importance to the metallurgist and to those engaged in the hot working and drawing of metals. It has not been the object, however, of this paper to draw particular attention to this aspect of the subject.

In conclusion the author wishes to express his indebtedness to Mr. E. Coupland, M.Sc., research assistant, and to Mr. J. Collins, M.Sc., research student, for the assistance they have given in connection with the experimental work described in this paper.

Shipbuilding and Shipping in Poland.—The Poland-Baltic Trading and Transport Company, which is co-operating with the Polish-American Company, has increased its capital to 60,000,000 marks, and it will eventually be increased to 120,000,000 marks. The company has purchased a large site on the Weichsel for the purpose of establishing a shipyard there, more expressly with a view to building steamers for river traffic.

Concrete Roads in Denmark.—Some official experiments with concrete roads have been undertaken in Denmark at the instance of the Viborg authorities on the Viborg-Aarhus high road. The experiments were carried on over a section some 350 m. in length and 4·5 metres wide, the camber being 1·50. The layer of concrete was 15 cm. thick and it was strengthened with ribs 25 cm. broad and 10 cm. deep along the sides. The top layer 5 cm. thick, was made of concrete with small stones ranging from 15 to 30 mm. in diameter, the mixture being 1 : 2 : 4 : whilst the formation layer was composed of gravel concrete mixed in the ratio 1 : 4 : 8. The top layer was placed upon the bottom layer immediately after the latter had been laid. For a short distance the concrete has been re-inforced with light longitudinal and cross rods placed 7 cm. from the surface in a layer of concrete 10 cm. thick. Three weeks were allowed for the hardening of the concrete before the road was opened for traffic. One part was tarred immediately and the remainder was left for a period of nine months for observation. The concrete road, in spite of fairly heavy traffic, has shown no cracks, and with the exception of a few isolated holes, about 1·5 cm. deep, it shows practically no signs of wear. The cost of the plain concrete portion amounted to 11–12 kr. per square metre, the value of the old road material partly covering the cost of making up and removal; the re-inforcement cost an additional 3 kr. per square metre, but the experiments have shown that the latter can be dispensed with under certain conditions.

CATALOGUES.

Electrical Machinery.—A catalogue received from the General Electric Company, Limited, 67, Queen Victoria-street, London, E.C. 4, gives illustrations and particulars of a 1,000-kw. rotary converter and its necessary gear designed for driving rolling and Pilger mills in a large steel works.

Telephones.—A revised list of prices of telephones, switchboards and accessories in the "K" section of their catalogue has been issued by the General Electric Company, Limited, 67, Queen Victoria-street, London, E.C. 4.

Cast-Iron Pipes.—A list of cast iron pipes in stock for immediate delivery, distinguishing the socket, flange and hydraulic types with the diameter, length, weight and quantity of each is issued monthly by the Stanton Ironworks Company, Limited, near Nottingham.

Leaf Binding.—A useful cover with transfer cases for binding single sheets of accounts, catalogues and commercial papers comes from Messrs. William Gibbons and Sons, Limited, Princess-street, Wolverhampton.

Concrete Reinforcement.—A catalogue of reinforcement made from sheet steel stamped into a rib form and suitable for walls, floors, roofs, arches and general building purposes, comes from the Trussed Concrete Steel Company, Limited, 22, Cranley Gardens, London, S.W. 17.

Electric Fuse Wires.—A price list of fuse wires made in aluminium, copper, tinned copper, lead, special alloy and pure tin, has been issued by the British Insulated and Helsby Cables, Limited, Prescot, Lancashire. Diameters and nominal fusing currents are mentioned in each case.

Magnetos.—Two magnetos of the four-cylinder type suitable, respectively, for heavy cars and lorries and for ordinary cars up to 20 h.p., are described, with full particulars and prices, in a small catalogue issued by the General Electric Company, Limited, 67, Queen Victoria-street, London, E.C. 4.

Electric Traction Motors.—Ventilated interpole traction motors, which are stated to be largely superseding the closed type, are described in detail with illustrations in a special catalogue issued by the British Thomson-Houston Company, Limited, Rugby. They are in extensive use in tramway plants.

Die-Cast Bearings.—Half bearings and bushes cast of a special metal to one-thousandth of an inch accuracy are offered by the Universal Die Casting and Metal Company, Limited, Farm-lane, Walham Green, London, S.W. 6. The catalogue contains a dimensioned diagram, and explains the importance of having metals with special characteristics for shafts and connecting rods.

Cutting Tools.—Tools with steel shanks and welded-on high-speed steel tips for use on lathes, planers and shapers, are shown in many standard forms in a catalogue issued by Messrs. Charles Churchill and Co., Limited, Leonard-street, Finsbury, London, E.C. 2. Dimensions and prices are stated.

Expansion Joints.—Several types of expansion joints for low-pressure steam pipe lines, are shown in a catalogue issued by the Griscom-Russell Company, 90, West-street, New York, they have cast steel flanges and copper barrels and are made in about 40 standard sizes ranging from 4 in. to 6 ft. in diameter.

Pneumatic Despatch.—A system of conveying letters, &c., to the various rooms in a building or to adjoining buildings is described in a catalogue received from Messrs. T. Cooke and Sons, Limited, Buckingham Works, York. The carriers which are of leather or fibre tube form open at one end, are forced through brass piping by air pressure. Hand or motor-driven air pumps are supplied.

Gas Welding and Cutting.—A 16 page booklet issued by the Davis Bournonville Company, Jersey City, U.S.A., contains a simple general description of a large range of tools and machines for cutting and welding with oxy-acetylene and oxy-hydrogen gas. The oxygraph, a machine for cutting steel plates from a ¼ in. thick to 15 in. thick, has a small electric motor and a tracer wheel which move the blowpipe along a path taken from a pattern or drawing, and copied by pantograph mechanism.

Oil Tractors.—The Advance Rumely Thresher Company, Laporte, Indiana, U.S.A., who have been making farming machinery for some eighty years, have issued a very complete catalogue of their oil engine tractor for farm work and also of their steam engines and other farm machinery. The figures of a test made under the auspices of the Ohio State University in January this year give the consumption of kerosene in this tractor, which is rated at 12 h.p. to 20 h.p., as 0·606 lb. per horse-power hour.

Pneumatic Hammers.—A catalogue of the Stevens-Hunter patent pneumatic tools, including hammers, holders-on, chisels, scalers, &c., comes from the Clement Stevens Pneumatic Engineering Company, Limited, High Wycombe, Bucks, who are the makers under sole licence. The various tools are fully illustrated and described with the usual special adaptations and sets of spare parts. The firm also make all the connections, compressors, &c., required for pneumatic power systems.

Automatic Clutches.—The automatic centrifugal clutches made by Messrs. Thomas Broadbent and Sons, Limited, Huddersfield, described in a special catalogue to hand from this firm, are intended for taking up the load gradually as a motor or engine runs up to normal speed. When desired they can be designed to begin to take up when the motor attains a certain proportion of its speed up to 75 per cent., and also to slip under a given amount of overload.

Separators.—The Griscom-Russel Company, 90, West-street, New York, send a catalogue of their appliance for separating moisture from compressed air, in which the wet air is given a spiral flow and then dashed against baffle plates on which the moisture is deposited ; also an appliance containing a wire strainer basket for separating solid matter from flowing water, oil, &c.

Heating and Cooling Machinery.—Messrs. Sulzer Brothers, Winterthur, Switzerland (and 31, Bedford square, London, W.C.1) send catalogues giving a general description of some installations of their refrigerating machinery for the meat trades and also of heating and cooling apparatus for use in cheese manufacture and storage. The latter, which is installed at Zollikofen, near Berne, is particularly interesting.

Marine Engines. Two catalogues of steam and oil marine engines come from one of the oldest engineering firms in the country—Messrs. Plenty and Son, Limited, Newbury. The steam engines made to standards include 14 powers in the triple expansion type, ranging from 95 i.h.p. to 900 i.h.p., and 20 powers in the compound type, ranging from 30 i.h.p. to 500 i.h.p. Inclined steam engines for stern-wheel and paddle boats are standard products of this firm, and horizontal marine engines are also shown. The latter are specially designed for ice-breaking vessels in which the head room is very limited. All steam engines are complete with boilers and connections. The marine oil engines include four sizes of 30, 50, 60, 100 brake horse-power provided with separate reversing gears and four of 90, 120, 150, 200 brake horse-power, which are directly reversible by means of compressed air. Separate reversing gears are supplied with all engines with one or two cylinders, while engines with three or more cylinders are directly reversible. These engines represent a substantial and economical class of machinery for harbour vessels, river craft and small ships, and many years experience is embodied in their design.

The "Brito-Latvian" Trade Fair.—As the name shows it was originally intended to confine exhibits to Great Britain and Latvia, but a number of circumstances, and amongst them the large number of applicants from other countries, made a change of plan necessary, and it was decided to give the Fair a more international character. It was this reason that chiefly led to the postponement of the opening from August 22 to the last week in September, and to the proposal that the Exhibition should be known as "The Riga Trade Fair." The Fair will be held on the premises of the former boot and leather factory, "Buffalo," Limited, 11, Weidendamm 30, Riga, and will have a duration of five weeks. Manufacturers of all nations will be represented, and amongst the advantages which this offers to the exhibitor from any one country is that there he will come into contact not only with local buyers, but with buyers and exhibitors from other countries, which will include Belgium, Finland, France, Great Britain, Scandinavia, &c., not to mention the opportunities which a resumption of commercial relations with Russia will offer in the near future. Further particulars may be obtained from The British and Russian Transport Company, Limited, 6, Lloyds-avenue, E.C.3.

Vibrations of a Marine Turbine.—A peculiar case of trouble with one of the turbines of a German torpedo boat is described in the *Zeitschrift des Vereines Deutscher Ingenieure*, of July 31 last by Captain-Lieutenant Hülcker and is discussed by several experts. As the boat in question was delivered up to the Allies before a thorough investigation could be held, the explanation is very doubtful. The boat was equipped with two turbine sets, each set of 13,000 h.p., consisting of ahead and astern turbine, being erected in a separate engine room, the port set aft of the starboard set, the shafting of the latter set was 7 m. longer than that of the former. The turbines passed their trials satisfactorily and gave, at 600 r.p.m., 32 knots. After a few months the starboard turbine suddenly refused to run at a speed above 200 r.p.m. There was no noise nor water hammer and no mud was found, and after removing the upper turbine cover nothing more than a very slight abrasion of some shrouding fins was discovered. By the aid of feelers it was ascertained that the clearance of about 3 mm. had not been affected in the lower inaccessible part of the turbine casing. The bearings were adjusted although they seemed to be all right, and the turbine was closed up again and ran at full speed as well as before. A few months afterwards, however, the same trouble reoccurred ; the speed would not rise above 200 r.p.m. and 17 knots. On re-opening the turbine some more abrasions were discovered, but the clearances were still normal. The turbine was again set to work after filing about 1 mm. off its shrouding fins, and the running became normal once more. In explanation Hülcker suggests that, as one of the three propeller blades would momentarily be in deep water, whilst the other two found smaller and unequal resistances in the water, the ship's stern would, at every revolution, receive three blows, obliquely to the propeller shaft. The ship in motion itself would vibrate longitudinally and by resonance excessive shaft vibrations might be set up. Professor Frahm doubts that explanation, and suggests rotor vibrations as the cause. Professor Föttinger, examining various possibilities in detail, suggested that a one-sided introduction of wet steam is more likely to be responsible by causing unequal heating and distortion of parts of the turbine casing, such as are sometimes observed when a turbine is slowly heated up. The peculiar point is that the speed would not rise above 200 r.p.m., although the steam pressure was increased from 2 atmospheres to 6 atmospheres in the first stage.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the communicators are given in italics.

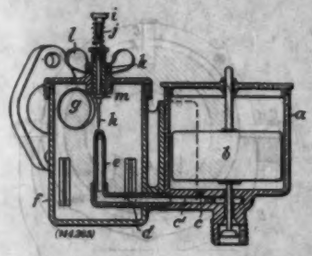
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 1s.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Act.

GAS ENGINES, PRODUCERS, HOLDERS, &c.

144,385. The Rt. Hon. Sir H. Norman, Westminster, and A. M. Low, Feltham. Carburetters. (1 *Fig.*) March 10, 1919.—The invention relates to carburetters such as are used with engines for the propulsion of auto-scooters, auto-wheels and other vehicles. *a* designates the float chamber containing the float *b* and communicating by channels *c*, *c*1 and connection *d* with the jet nozzle *e* in mixing chamber *f* from which the charge is passed to the engine through pipe *g*. In alignment with the axis of the nozzle *e* is disposed a needle A extending to the exterior of the chamber *f* and provided at its upper end with a knob *i*. The said needle is under the action of a spring *j* tending to keep it raised out of engagement with the nozzle as shown in



the drawing, but when it is desired to clean the nozzle, all that is necessary is to depress the knob, thereby causing the needle to enter the nozzle aperture and clear same of any obstruction which may be present. For the purpose of giving if desired a fixed adjustment to the needle after having used same for clearing the nozzle in order to control the flow of liquid fuel through said nozzle, the needle is shown as carried by a boss *k* screw threaded into the cover of chamber *f* so that it is adapted for vertical adjustment in said cover, a wing nut *l* being provided for securing the boss in its positions of adjustment. The needle is shouldered at *m* so that it follows the screw-down adjustment of the boss. (*Accepted June* 23, 1920.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

144,339. A. W. Bennis, Bolton. Clutches. (3 *Figs.*) January 14, 1919.—The invention relates to improvements in power transmission clutches or overload release gear adapted to disengage at a predetermined load, of the type in which the driving element is connected to the driven element by a coupling comprising a pin or roller carried in a pivoted arm on one element and held by spring means in a recess in the other element. According to the invention, the pin is carried on one end of an arm pivoted to a crank on one element, being loaded by an adjustable spring attached at a point along said pivoted arm. A driving shaft 1 has loosely running upon it the boss 2 of a pulley 3 which may be adapted to drive any element. Mounted upon the shaft 1 is a boss 4 integral with a crank 5 having a pivot 6 for the arm 7 which is connected intermediate its length by means of a pivot pin 8 to a rod 9 passing through a cut away portion or slot 10 on an extension arm 11 projecting from the boss 4, and which rod 9 is controlled by a spring 12 adjustable

Fig. 1.

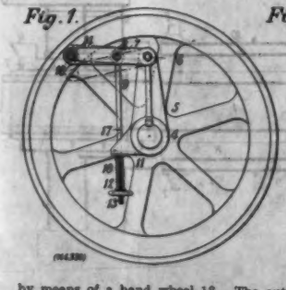


Fig. 2.

by means of a hand wheel 13. The outer edge of the driving pin 14 has a roller 15 similar to the pin and roller of a roller chain. The pulley 3 carries on its rim an open pocket 16 which is formed on a detachable bolt to engage with and partially enshroud the driving pin and roller 14 and 15, the projection of the pocket 16 around the pin and its roller 15 being set at such an angular relation to the centre line drawn through the pivot of the arm and the pin 14 that a comparatively light pressure by spring 12 is necessary to hold the pin 14 inside the pocket 16. The pin 14 and its roller 15 will be held in pocket 16 by the spring pressure or tension until the load becomes too great when the pin, or the roller 15 upon it slips out of the pocket 16 and the spring pressure draws away the roller 15 from this pocket 16 so that the pulley remains stationary while the driving crank 5 continues to revolve but without driving the pulley 3 or other driven member. The rod 9 may be provided with a pin 17 to prevent its range of motion being too great. (*Accepted June* 23, 1920.)

144,070. A. Smith, Keighley. Feed Mechanism of Lathes. (8 *Figs.*) 21 May, 1919.—The invention relates to traverse or feed motion mechanism for lathes of the type in which the operating screw has left and right hand threads in order to operate the feeding or traverse mechanism in one direction or the other as desired. This screw has acting in conjunction with it two nuts provided with right and left handed threads respectively either of which nuts may be held as to cause traverse of the saddle in one direction or the other. The invention consists in the means for holding the nuts when desired against rotation or to clutch them against said screw. Two nuts *b* and *b*1 provided respectively with flanges *b*2 and *b*5 are employed. Cam surfaces *c*, *c*1 are formed on the flanges *b*2, *b*5. Intervening between the nuts *b*, *b*1 is a web *d* having an opening therein for the reception of a sliding bolt *d*1, said bolt being made to slide in the direction of the length of the operating screw *e* while the web *d* forms part of the framework in which are placed the parts which have fitting within them the nuts *b*, *b*1 that have to be moved or operated by said screw *e*. The sliding bolt *d* is operated by the crank pin *e*1 of a spindle *e*, this

Fig. 1.

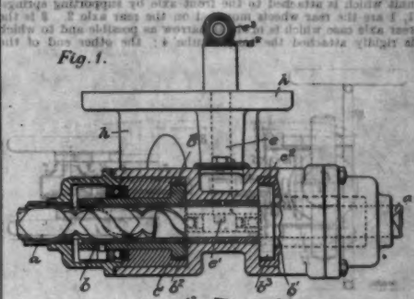
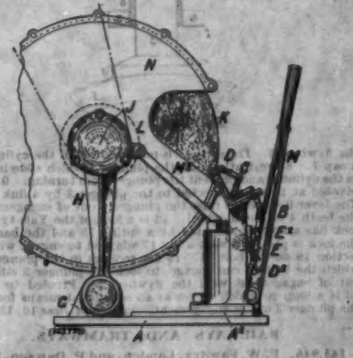


Fig. 2.

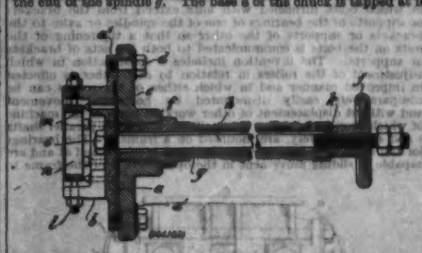
being rotated by gears *e*2, *e*3 and by means of a shaft extending to the front of the machine, said shaft having an operating handle by means of which it can be oscillated to cause the sliding of the bolt *d*1. Within the part *d* are mounted balls *g* against which press two spindles *g*1 of the bolt *d*1 and according to the position of the crank pin *e*1 one of the balls *g* will be pressed firmly against either the undulating surface *c*1 of the flange *b*3 of the nut *b*1 or against the flange *b*2 of the nut *b*. When the ball *g* is thus moved against the cam surface *c* or *c*1 of either of the nuts *b* or *b*1 the rotary motions of said nut as caused by the screw *a* are arrested and said nut is held against rotation by the wedging of the ball *c* on the inclined parts of the undulating surface *c*1. When the nut is thus held against rotation the motions of the screw *a* are such as to cause said nut to traverse longitudinally over the said screw *a* and carry with it the part *h*. This part is fixed to the saddle, hence the latter is at this time traversed along the bed of the lathe. (*Accepted June* 16, 1920.)

143,778. L. Leigh, Southport. Abrasive Cutting-Off Machines. (2 *Figs.*) September 19, 1919.—The invention relates to abrasive cutting-off machines of the type employing a cutting wheel which is mounted in a frame hinged to a support in such manner that the said wheel can be moved in its plane of rotation to or from the work to be operated upon. According to this invention, the work is mounted upon a support which can be adjusted angularly about an axis transverse to that of the abrasive cutting wheel. A is a base plate to machined surfaces A2 of which is bolted a support for the work. This comprises a pair of pillars B between which is a channel C in which the work, generally bar material, lies. Chains D are attached at one end to the channel C and their free ends pass over the work and are acted upon by a screw device. A cross member D2 connecting together the ends of the chains D is acted upon by a slide E provided with hooks E2 engaging the cross-member. This slide is guided



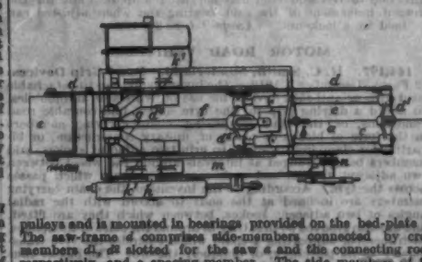
between the pillars B, and is acted upon by a screw, the tightening of which exerts a tension on the chains D and holds the work firmly in the channel C. The pillars B are connected together and can swivel slightly on the baseplate A, so that the work may be cut-off at various angles, and may be adjustable towards the wheel. The baseplate A is formed with a bored boss G, in which lies the pivot pin of the wheel-carrying frame. This comprises a pair of arms H joined together and carrying ball bearings for the cutting spindle J. The abrasive cutting disc K, which is an elastic or flexible grinding wheel is located outside an arm H and the spindle carries a belt pulley L between the arms. A lever M is pivoted to the baseplate A and is connected by the link M3 to the arms. By the movement of this lever the arms H are rocked about their pivot and the abrasive cutting wheel moved towards or away from the work. The abrasive cutting wheel is enclosed in a two-part guard N, which encloses the major part of the wheel. (*Accepted June* 16, 1920.)

144,163. Ransome and Marles Bearing Company, Limited, Newark-on-Trent, and J. D. Scaife, Newark-on-Trent. Chuck. (3 *Figs.*) September 17, 1919.—The invention relates to improvements in chucks for use in connection with machine tools. The body of the chuck is made of metal and comprises a more or less flexible disc like base or flanged body portion *a* carrying on its face a plurality of circularly arranged lugs *b* formed integrally with the base and divided from one another by means of radial slots. The base portion *a* of the chuck is relieved or thickened at *a*1 at or near its outer edge and is secured by bolts *d* to a second or rigid carrier plate *e* which is adapted to be fixed to the machine. In the case of a grinding machine it could be formed with a central boss *f* and be fixed to the end of the spindle *g*. The base *a* of the chuck is tapped at its



centre to engage the end of an axial draw bolt A which is secured thereto by means of a lock nut *i*. This bolt A passes through the hollow spindle *g* of the machine to the opposite end where it is screw threaded and provided with a hand operating wheel *j* bearing on a thrust washer *k* in the end of the said spindle *g*. In operation, when this wheel is screwed up it operates the draw bolt A and springs the disc like base *a* of the chuck, thus causing the lugs *b* thereon forming the jaws of the chuck to move radially inwards to hold the work in a central position. In each lug *b* an adjustable binding screw *l* is provided to engage the work *n* as well also as a plurality of locating pins *m* for work to rest upon when in position. (*Accepted June* 16, 1920.)

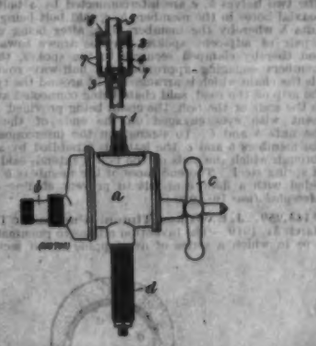
144,120. E. Coles, Bury. Saw. (4 *Figs.*) July 7, 1919.—The invention relates to power-driven reciprocating saws and in particular to cross-cut saws for sawing logs. According to the invention, the frame is supported by a support independent of, but co-axial with, the shaft from or by which the saw is reciprocated. *a* is the saw attached to a cross-head *b* mounted to slide on guides *c* carried at one end of the saw-frame *d* which at its other end carries the counterbalance weight *e*. The cross-head *b* is reciprocated through the medium of the connecting rod *f* by the crank *g*, the shaft *h* of which is provided with fast and loose



pulleys and is mounted in bearings provided on the bed-plate *m*. The saw-frame *d* comprises side-members connected by cross members *d*1, *d*2 slotted for the saw *a* and the connecting rod *f* respectively, and a spacing-member. The side members of the saw frame are formed with bosses *d*3 which are mounted on reduced bosses *k*1 integral with the bearings and projecting from the inner faces thereof concentrically with the axes of the bearings and the crank-shaft A. The feed of the saw is effected by a pinion *n* mounted on the saw-frame and provided with an operating handwheel co-acting with a toothed quadrant mounted on the bed-plate *m*. (*Accepted* June 16, 1920.)

MINING, METALLURGY, AND METAL WORKING.

143,732. C. H. Stevens, London. Pneumatic Drills. (1 *Fig.*) June 10, 1919.—The invention relates to pneumatic drills and provides means whereby when such drills are being used under water provision is made for exhausting from the motor cylinders into the crank chamber and drill casing, and from thence into the water by way of a non-return valve, which is spring-loaded and so adjusted that it opens only when the exhaust air in the motor casing is at a slightly higher pressure than that of the water surrounding the drill casing. *a* is the casing enclosing

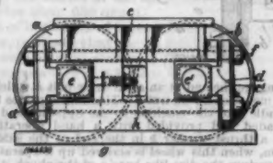


the reciprocating pistons pneumatically driven and rotating a crankshaft connected with the drill. The drill extends through the casing at *b* and is fed by the hand wheel *c*, while *d* is the inlet for the compressed air. The casing *a* is provided with a pipe or tube 1 terminating at its outer end in the inlet passage of a valve casing 2. This inlet passage is closed by a valve 3 which is held on its seating by a spring 4, while the valve spindle 5 works in a cover 6. This cover is screwed into the valve casing and forms an abutment for the spring 4, the pressure of which on the valve 3 is adjusted by means of said cover. The casing 2 is formed with perforations 7 to permit of the escape of air admitted into

the casing by the valve 8. The load of the spring 4 on the valve 8 is adjusted so that the pressure required to open the valve is slightly higher than the head of water in which the drill is working, thus maintaining within the casing a pressure which is greater than that outside the casing, thereby preventing leakage of water through the joints or other parts of the casing. (*Accepted June 9, 1920.*)

MILLING AND SEPARATING MACHINERY.

144,481. D. H. Bibb, London. Crushing Machines. (1 *Fig.*) May 14, 1919.—The invention relates to means for adjusting the bearings, and consequently the axles or spindles, of the rollers of moulding and crushing machines of that kind in which bolts furnished with nuts extend from the brackets or supports of the bearings of one of the spindles or axles to the brackets or supports of the other so that a tightening of the nuts on the bolts is communicated to both the sets of brackets or supports. The invention includes a construction in which adjustment of the rollers in relation to each other is effected in improved manner and in which either of the rollers can be comparatively easily dismounted by horizontal movement and without displacement of other working parts of the machine of which they form part. Two rollers *a* and *b*, on parallel shafts *c* and *d* respectively, are mounted on a frame *e*. The bearings for the shafts are held in place by head blocks *f* and *d*1 and are capable of sliding movement in the open ends *e*1 of the frame so



that they can be placed in and drawn out horizontally and thus their respective rollers independently moved. The head blocks are held to the frame *e* by bolts and nuts *f*, *f* which are passed through the said frame and it will be evident that any tightening of the nuts on the bolts will tend to pull the head blocks towards each other and thereby draw the shafts of the rollers closer together. The bearings of the shaft *d*1 are placed as far into their open ends of the machine as they will go and the bearings for the shaft *c* are put in but left with a clearance, for adjustment, between them and the inner portion of the open ends into which they are placed. To limit the inward movement of the shaft *c* an opening *h* is provided in the frame *e* and from this a threaded hole is formed towards the bearings of the shaft *e*. In this threaded hole a square headed stud *g* is fitted, by the turning of which the said bearings can be pushed in an outward direction or the said stud may act as a stop or limit for the inward movement of the said bearing and when adjusted can be held by a lock nut. (*Accepted June 23, 1920.*)

MOTOR ROAD VEHICLES.

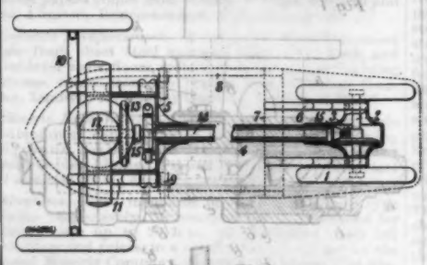
144,197. H. C. Smith, Sunderland. Road Grip Devices. (2 *Figs.*) December 3, 1919.—The invention relates to detachable road grip or anti-skid devices for use on wheels of automobiles, to afford a driving grip for the tyre under unfavourable road conditions, of the kind comprising chain carrying members in the form of blocks or plates of unitary construction, or bipartite for clamping together, to grip two adjacent spokes, said members being arranged at intervals around the wheel between two adjacent spokes, and each carrying a chain which passes across the tyre. According to the invention, the chain carrying members are inclined at the ends to accord with the radial angles of two adjacent spokes, between which they are fitted, and are also grooved so that they fit around the sides of the spokes, each member supporting a chain which encircles the tyre transversely to its periphery, or obliquely thereto. The blocks thus formed may be in one piece or bipartite, the two halves in the latter case being clamped together to engage between them, opposite sides of two adjacent spokes. *a* is the chain supporting member comprising two similarly shaped correlated halves *b*, *c*,

the ends of which are inclined to accord approximately with the radial angles of the spokes of an automobile wheel and are also grooved as shown at *f* to conform substantially with the cross sectional outline of the spokes to which they are to be fitted. The two halves *b*, *c* are interconnected by a bolt *g* disposed in coaxial bores in the members *b*, *c*, said bolt being provided with nuts *h* whereby the members *b*, *c*, after being placed between a pair of adjacent spokes may be drawn towards each other and thereby clamped securely to the spokes, the ends of the members engaging approximately half-way round the spoke. *i* is the chain which is arranged to fit around the tyre and affords the grip on the road, said chain being connected at opposite ends to the ends of the bolt, the chain being provided for its attachment with eyes engaged on the ends of the bolt between the nuts *h* and *l*. To strengthen the interconnection between the members *b* and *c*, the latter is straddled by a yoke plate *m* through which the ends of the bolt *g* extend, said plate *m* being of spring steel. The end faces of the members *b* and *c* are provided with a liner *k* of felt to prevent chafing of the spokes. (*Accepted June 16, 1920.*)

143,959. J. E. Wilkes, Tipton. Pneumatic Tyre. (2 *Figs.*) March 31, 1919.—The invention relates to pneumatic tyres of the type in which a series of overlapping metal sections or plates

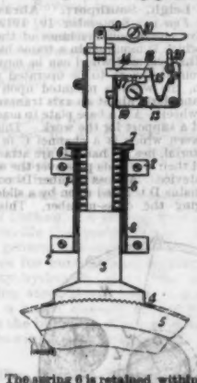
attached to the tyre or cover are arranged in annular form between the cover and the inner tube to form a metal sheathing for the purpose of preventing punctures. According to the invention, a strip of canvas unattached to the sections or plates is directly attached along one of its longitudinal edges to the tyre or cover, and said canvas has its other edge free so that it can be readily moved away from the sections or plates for inspection or repair purposes. The device comprises a series of sections *a* of substantially semi-circular cross-section and curved circumferentially of the tyre to conform with the internal surface thereof. These sections overlap each other, for which purpose each section is at each extremity offset a degree equal to the thickness of the metal, to provide a flush inner surface. Each section is secured to the tyre cover by a rivet *a*. *d* is a flap of canvas which is secured to the inner surface of the tyre cover at *c*, and which protects the inner tube from the sections *a*. (*Accepted June 16, 1920.*)

144,086. S. B. Weller, Surbiton, and J. Weller, Surbiton. Motor Vehicle. (2 *Figs.*) May 31, 1919.—The invention relates to four-wheeled motor vehicles and more especially to small vehicles of the runabout type. According to the invention, the rear wheels are mounted as closely together as possible, one on either side of a narrow axle case which is supported by springs situated between the said wheels, and the engine bed, torque tube and rear axle case are constructed as a single rigid unit which is attached to the front axle by supporting springs. 1, 1 are the rear wheels mounted on the rear axle 2. 3 is the rear axle case which is made as narrow as possible and to which is rigidly attached the torque tube 4; the other end of the



torque tube 4 is rigidly attached to the engine bed 5; the engine bed, torque tube 4 and rear axle case 3 thus form a single rigid unit. The rear axle case is supported by springs 6 which are situated between the rear wheels 1 and are attached to a cross bar 7 connected to radius rods 8 pivoted at 9. The engine bed 5 is attached on either side to the front axis 10 by springs 11. The engine 12 has the axis of its crank shaft arranged vertically and is situated over the friction wheel 13 which is housed in the engine bed 5 and can be slid upon the propeller shaft 14 which is carried by two self-aligning ball bearings 15. The drive is transmitted by the propeller shaft 14 to the rear axle 2 by bevel gear 16. (*Accepted June 16, 1920.*)

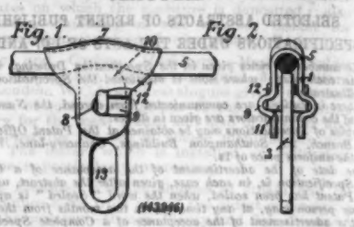
144,154. E. A. Mitchelson, London. Engine Locking Device. (1 *Fig.*) October 11, 1919.—The invention relates to an engine locking device of the type in which the flywheel is prevented from turning by means of a plunger adapted to engage therewith and in which means are provided to prevent the withdrawal of the plunger out of engagement. According to the invention, the plunger is provided with a toothed segment adapted to engage with teeth on the engine flywheel. 1 is a cylinder having lugs 2 by which it is secured to the frame of an automobile. Slidably mounted within the cylinder 1 is a plunger 3 having at its lower end a toothed segment adapted to engage with ratchet teeth 4 on the engine flywheel 5. 6 is a spring adapted to press the teeth of the plunger 3 into engagement with the teeth on



the flywheel 5. The spring 6 is retained within the cylinder 1 by a cap 7. 8 are feathers on the plunger 3 which slide in grooves in the cylinder and prevent the plunger from turning. 9 is a lever pivoted at 10 and connected to the plunger 3 by a link and pin. The lever 9 serves to raise the plunger 3 out of engagement with the teeth 4 on the flywheel. 13 is a lock of the Yale type. The lock has a bolt 14 actuated by a spring 15 and the barrel 16 of the lock is provided with a lug 17 adapted to engage with a projection 18 on the bolt 14. 19 are recesses in the plunger 3 with which the bolt 14 can engage, to lock the plunger 3 either in or out of engagement with the flywheel 5. Pivoted to the lock 13 is a loop 20 which serves as an additional means for holding the plunger 3 out of engagement. (*Accepted June 16, 1920.*)

RAILWAYS AND TRAMWAYS.

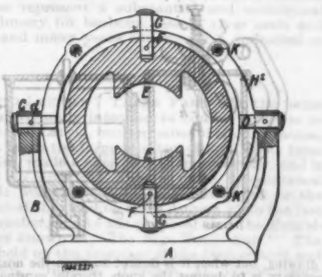
143,946. F. W. Fawdry, London, and P. Dawson, London. Overhead Trolley Wires. (2 *Figs.*) August 19, 1919.—The invention relates to supporting devices for overhead trolley wires for use on electric railways and tramways. A stirrup 1 recessed internally at 7 is provided with slots 8, one side of each of which opens into a semi-cylindrical groove 9 formed by pressing or stamping out of the body of the metal of which the stirrup is formed. A cam member 3 has a rounded portion 10, and has trunnions 11 grooved on their upper sides to form lugs 12. The lower end of the cam is provided with a slot 13 which serves for attaching thereto the dropper wire. In assembling the device, the stirrup 1 is placed in position on the wire 5 and the cam member 3 introduced from the right-hand side, the cam being held in a direction parallel to the wire 5 so that the trunnions 11 pass through the grooves 9. When the trunnions have passed completely through said grooves and have become seated in the slots 8, the cam member is rotated by any suitable means, the trunnions acting as a pivot, until the edges of the lugs 12 engage the inner edges of the portions forming the grooves 9. During this operation the cam member presses the wire 5 into the recess 7 until stirrup wire and cam member become securely locked together, a three-point contact being produced at the ends of the



stirrup and between the cam and the middle portion of the bent part of the catenary wire. The dropper wire is secured through the slot 13 subsequently to the operations described above and by its pull in a downward direction assists in maintaining the cam member 3 in locking position. (*Accepted June 16, 1920.*)

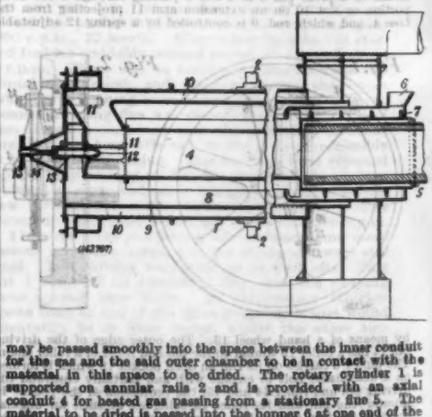
MISCELLANEOUS.

144,227. C. H. Vidal, Croydon, and A. Ketteiwell, Croydon. Gimbal Rings. (2 *Figs.*) February 13, 1920.—The invention relates to gimbal rings and consists in the arrangement by which the ring is made in two annular parts which are secured together by means which allow of the separation of the parts and ready access to the appliances mounted on the ring. A is a base plate carrying arms B in which bearings C are provided for pins D on which the gimbal ring is pivoted so as to turn about the axis passing through both pins. The pins



D are secured to the bearings C by set screws d. The field magnets E of an electric fan are secured at F to pins G disposed to allow the magnet to turn about an axis joining these pins at right angles to the axis passing through the pins D. The gimbal ring is made in two parts secured together by countersunk screws K; the withdrawal of the screws enables one portion of the ring to be removed leaving the pins D in the supporting arms B and the pins G and the field magnets E supported by the part H2 of the ring. The motor can then be removed. (*Accepted June 16, 1920.*)

143,707. A. A. Short, Derby, and W. G. Watkins, Derby. Drying Machinery. (1 *Fig.*) May 16, 1919.—The invention relates to drying machinery of the type in which a heated stream of air or gas is passed through a rotating drum, firstly in one direction and then back in the other direction, means such as valve control being provided if desired so that the heated gases may pass through the rotating chamber either in contact with the material to be dried or to split it so that part passes through a jacket on the rotating chamber whilst the other part passes in contact with the material to be dried. According to the invention, the control valve arranged axially on the rotating drying chamber has a poppet or mushroom head so that the gases passing axially around the rotating drying chamber are smoothly deflected to a longitudinal jacket over the outside surface of which the material to be dried passes and providing that when the valve is in the open position an adjustable proportion of these gases



may be passed smoothly into the space between the inner conduit for the gas and the said outer chamber to be in contact with the material in this space to be dried. The rotary cylinder 1 is supported on annular rails 2 and is provided with an axial conduit 4 for heated gas passing from a stationary fine 5. The material to be dried is passed into the hopper 6 at one end of the cylinder 1 and fed by a conveyor 7 into the space 8 between the conduit 4 and the internal wall 9 of the chamber 10, coaxial with the conduit 4. Passages 11 lead the heated gas which is passed down the conduit 4, into the chamber 10. The end of the conduit 4 is normally closed by a poppet or mushroom head valve 12, the spindle 13 of which is internally threaded to receive the threaded shaft 14 rotated by a hand wheel 15, by means of which the valve 12 may be withdrawn to an adjustable extent from the end of the conduit 4 to allow an adjustable quantity of heated gas to pass into the space 8 instead of all this gas passing backwards along the chamber 10. (*Accepted June 16, 1920.*)